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NATIONAL DAM SAFETY PROGRAM. LAKE WATERLOO DAM (NJ-00276), DELA--ETC(U)
AUG 79 R J MCDERMOTT, J E GRIBBIN DACW61-79-C-0011

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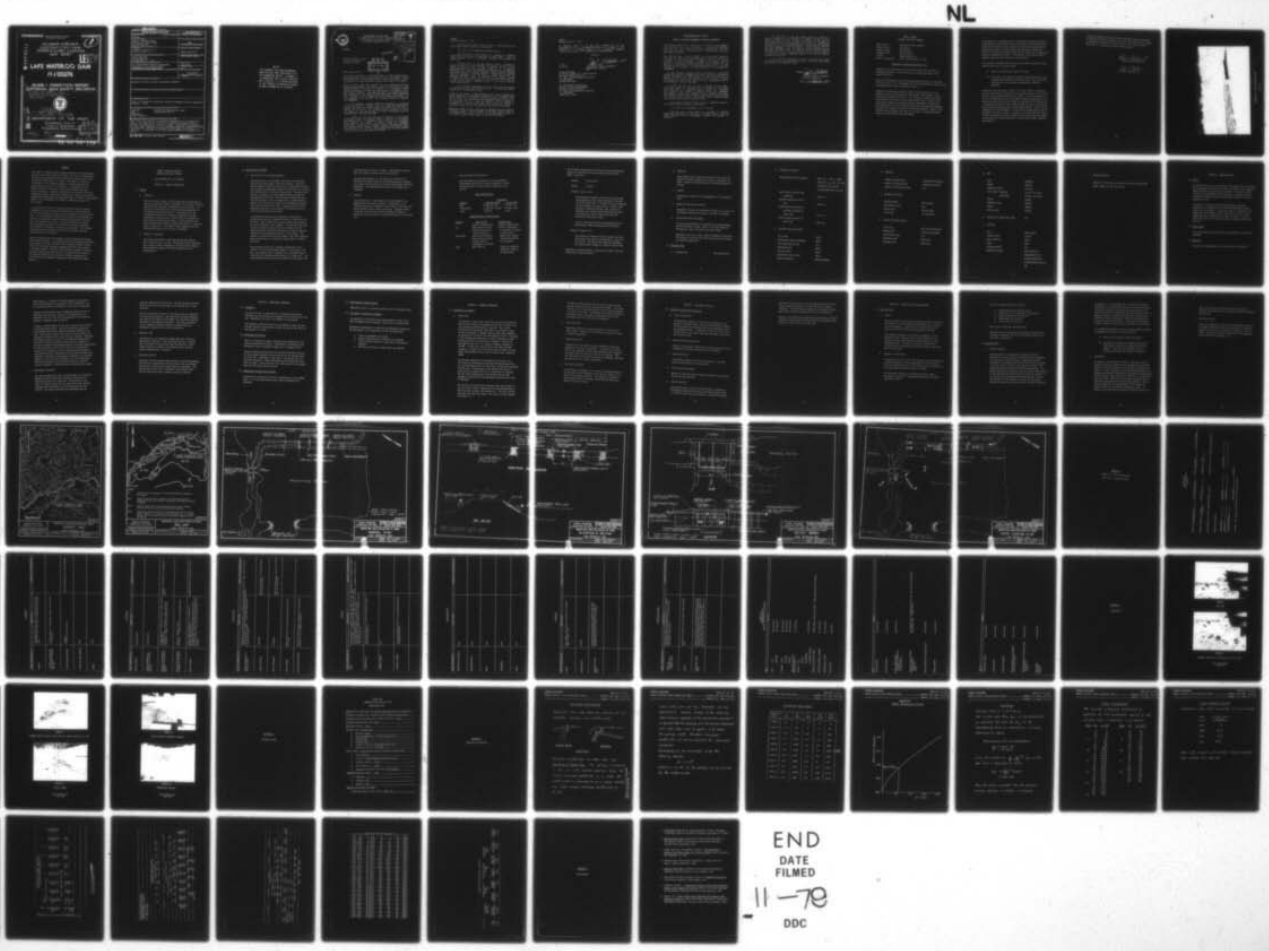

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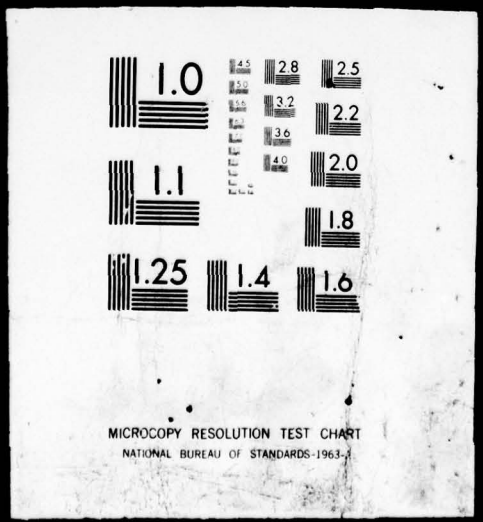

DELAWARE RIVER BASIN
MUSCONETCONG RIVER,
MORRIS & SUSSEX COUNTIES
NEW JERSEY

LEVEL II

LAKE WATERLOO DAM
NJ 00276

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Lake Waterloo Dam (NJ-00276). Delaware River Basin. Musconetcong River, Morris and Sussex Counties, New Jersey. Phase 1 Inspection Report.

(9) Final rept.

(10) Richard J. /McDermott
John E. /Gribbin

(15) DACW61-79-C-0011

DEPARTMENT OF THE ARMY
Philadelphia District
Corps of Engineers
Philadelphia, Pennsylvania

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7. AUTHOR(s): McDermott, Richard J. P.E. Gribbin, John E., P.E.	8. CONTRACT OR GRANT NUMBER(s): DACW61-79-C-0011
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Copies are obtainable from National Technical Information Service, Springfield, Virginia, 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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Visual inspection
National Dam Inspection Act report
Lake Waterloo Dam, N.J.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE - 2 D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO

NAPEN-D

20 SEP 1979

Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, NJ 08621

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Lake Waterloo Dam in Morris and Sussex Counties, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Lake Waterloo Dam, initially listed as a high hazard potential structure, but reduced to a significant hazard potential structure as a result of this inspection, is judged to be in poor overall condition. The dam's spillway is considered inadequate since 28 percent of the Spillway Design Flood--SDF - would overtop the dam. (The SDF, in this instance, is the One Hundred Year Flood.) To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980.

b. Within one year from the date of approval of this report, engineering studies and analyses should be performed to investigate the repairs made at the embankment breach locations and to determine their adequacy and prepare a detailed design for embankment improvements, including any necessary filling, regrading and riprap. These studies should include a complete inspection and detailed design for renovation of the spillway. Any remedial measures found necessary should be initiated within calendar year 1980.

c. The following remedial actions should be completed within one year from the date of approval of this report:

(1) Trees on the embankment should be removed.

(2) The outlet works should be renovated by patching deteriorated concrete and coating with an epoxy sealant. Also the timber stoplogs should be thoroughly inspected and replaced if necessary.

(3) The owner of the dam should initiate a program of periodic inspection and maintenance, the complete records of which should be kept on file. A visual inspection of the dam and appurtenances should be made annually and reported on a standardized check-list form. Repairs should be made as required and the following maintenance should be performed annually: remove adverse vegetation from the embankment, fill and sod any eroded surfaces of the embankment and repair riprap. In addition, the lake should be lowered at least once every five years at which time the lake should be cleaned and the normally submerged portions of the dam and spillway inspected and repaired.

(4) A detailed topographic survey of the dam and area around the dam based on USGS datum should be made. The survey map should become part of the permanent record.

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman James A. Courter of the Thirteenth District. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

NAPEN-D
Honorable Brendan T. Byrne

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,

Joel Kollmorgen LTC

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Copies furnished:
Mr. Dirk C. Hofman, P.E., Deputy Director
Division of Water Resources
N.J. Dept. of Environmental Protection
P.O. Box CN029
Trenton, NJ 08625

Mr. John O'Dowd, Acting Chief
Bureau of Flood Plain Management
Division of Water Resources
N.J. Dept. of Environmental Protection
P.O. Box CN029
Trenton, NJ 08625

LAKE WATERLOO DAM (NJ00276)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 1 May and 13 July 1979 by Storch Engineers under contract to the State of New Jersey. The State, under agreement with the U.S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Lake Waterloo Dam, initially listed as a high hazard potential structure, but reduced to a significant hazard potential structure as a result of this inspection, is judged to be in poor overall condition. The dam's spillway is considered inadequate since 28 percent of the Spillway Design Flood--SDF - would overtop the dam. (The SDF, in this instance, is the One Hundred Year Flood.) To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980.

b. Within one year from the date of approval of this report, engineering studies and analyses should be performed to investigate the repairs made at the embankment breach locations and to determine their adequacy and prepare a detailed design for embankment improvements, including any necessary filling, regrading and riprap. These studies should include a complete inspection and detailed design for renovation of the spillway. Any remedial measures found necessary should be initiated within calendar year 1980.

c. The following remedial actions should be completed within one year from the date of approval of this report:

(1) Trees on the embankment should be removed.

(2) The outlet works should be renovated by patching deteriorated concrete and coating with an epoxy sealant. Also the timber stoplogs should be thoroughly inspected and replaced if necessary.

(3) The owner of the dam should initiate a program of periodic inspection and maintenance, the complete records of which should be kept on file. A visual inspection of the dam and appurtenances should be made annually and reported on a standardized check-list form. Repairs should be made as required and the following maintenance should be performed annually: remove adverse vegetation from the embankment, fill and sod any eroded surfaces of the embankment and repair riprap. In addition, the lake should be lowered at least once every five years at which time the lake should be cleaned and the normally submerged portions of the dam and spillway inspected and repaired.

(4) A detailed topographic survey of the dam and area around the dam based on USGS datum should be made. The survey map should become part of the permanent record.

APPROVED: Jul Kelleher

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

DATE: 19 September 1979

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Lake Waterloo Dam, NJ00276
State Located:	New Jersey
County Located:	Morris/Sussex
Drainage Basin:	Delaware River
Stream:	Musconetcong River
Dates of Inspection:	May 1, 1979 and July 13, 1979

Assessment of General Condition of Dam

Based on visual inspection, past operational performance and Phase I engineering analyses, Lake Waterloo Dam is assessed as being in poor overall condition.

Based on investigations of the downstream flood plain made in connection with this report, it is recommended that the hazard potential classification be downgraded from high to significant hazard.

Hydraulic and hydrologic analyses indicate that the spillway is not adequate to pass the designated spillway design flood (100-year storm) without an overtopping of the dam. The spillway is capable of passing approximately 27 percent of the spillway design flood. Therefore, the owner should engage a professional engineer experienced in the design and construction of dams in the near future to perform detailed hydraulic and hydrologic analyses relating to the spillway capacity. Based on the findings of the analyses, the need for and type of mitigating measures should be determined and then implemented.

In addition, it is recommended that a professional engineer experienced in the design and construction of dams be engaged in the near future to investigate the repairs made at the breach locations to determine their adequacy and prepare a detailed design for embankment improvements, including any necessary filling, regrading and riprap, and the embankment should be renovated accordingly. This remedial work should include a complete inspection and renovation of the spillway.

It is further recommended that the following remedial measures be undertaken by the owner in the near future.

1) Trees on the embankment should be removed.

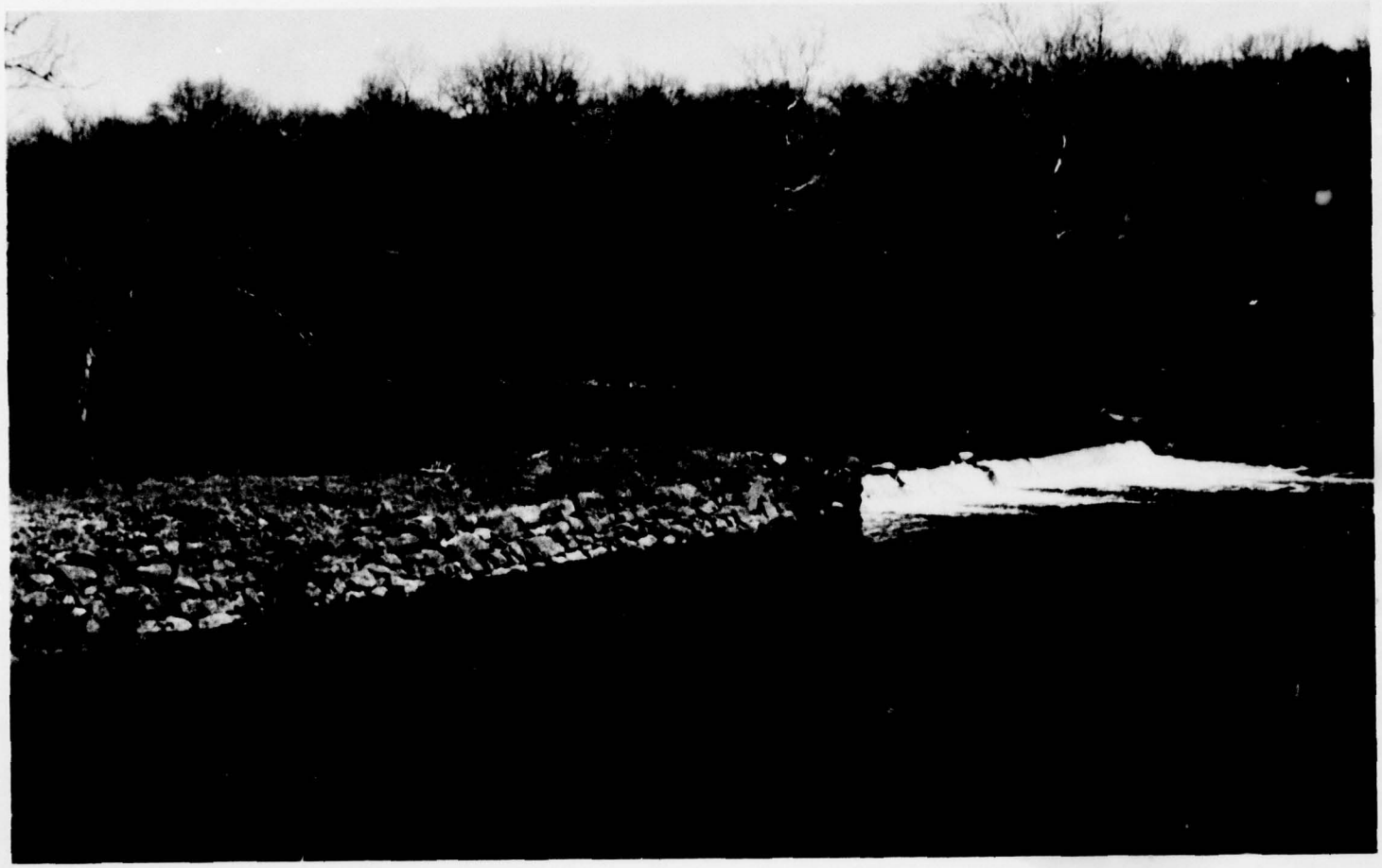
2) The outlet works should be renovated by patching deteriorated concrete and coating with an epoxy sealant. Also, the timber stoplogs should be thoroughly inspected and replaced if necessary.

The owner of the dam should initiate, in the near future, a program of periodic inspection and maintenance, the complete records of which to be kept on file and made available to the public. A visual inspection of the dam and appurtenances by a professional engineer experienced in the design and construction of dams should be made annually and reported on a standardized check-list form. Repairs should be made as required and the following maintenance should be performed annually: remove adverse vegetation from the embankment, fill and sod any eroded surfaces of the embankment and repair riprap. In addition, the lake should be lowered at least once every five years at which time the lake should be cleaned and the normally submerged portions of the dam and spillway inspected and repaired.

A detailed topographic survey of the dam and area around the dam based on USGS datum should be undertaken by a qualified licensed land surveyor or professional engineer in the near future. The survey map should become part of the permanent record mentioned above.

Richard J. McDermott, P.E.

John E. Gribbin, P.E.



OVERVIEW - LAKE WATERLOO DAM

1 MAY 1979

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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 30214. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that the unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

LAKE WATERLOO DAM, I.D. NJ00276

SECTION 1: PROJECT INFORMATION

1.1 General

a. Authority

Public Law 92-367, August 8, 1972 authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The Division of Water Resources of the New Jersey Department of Environmental Protection (NJDEP) in cooperation with the Philadelphia District of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the State of New Jersey. Storch Engineers has been retained by the NJDEP to inspect and report on a selected group of these dams. The NJDEP is under agreement with the Philadelphia District of the Corps of Engineers.

b. Purpose of Inspection

The visual inspections of Lake Waterloo Dam were made on May 1, 1979 and July 13, 1979. The purpose of the inspections was to make a general assessment of the structural integrity and operational adequacy of the dam structure and its appurtenances.

1.2 Description of Project

a. Description of Dam and Appurtenances

Lake Waterloo Dam is an earthfill dam with a free overflow spillway and outlet works fitted with stoplogs. Having an overall length of 496 feet, the dam has a top width of 15 feet and upstream and downstream slopes of 5 horizontal to 1 vertical and 2 horizontal to 3 vertical, respectively. The majority of the dam is oriented in a north-south direction (across the Musconetcong River) with a short section oriented east-west. The short section, which is located along a raceway channel, adjoins the main portion of the dam at a 90-degree bend point near the north bank of the river. Riprap covers the entire downstream face and a small section of the upstream face of the north-south portion of the dam.

A concrete box structure with stoplogs on three sides is constructed across the raceway and serves as outlet works for the lake. Water flowing in the raceway enters the structure by way of upstream or east stoplogs. Flow may then discharge from the structure by way of the south stoplogs into the downstream channel (Musconetcong River) or by way of the west stoplogs into the downstream portion of the raceway. The raceway is located along the north edge of the river conveying water from the dam to a restored millhouse where it rejoins the river.

The spillway consists of a straight concrete weir with a length of 76 feet located approximately in the center of the dam. The upstream face is composed of an inclined concrete slab while the downstream face consists of a timber wall. The crest elevation of the spillway is 648.0 (N.G.V.D.) while the

crest elevation of the dam is 649.8. Stone masonry training walls are located on both sides of the spillway.

The downstream channel, in the vicinity of the dam, is a 200-foot wide shallow reach of the Musconetcong River between the subject dam and another dam located approximately 1000 feet downstream. The entire downstream toe of the subject dam is submerged.

b. Location

Lake Waterloo Dam is constructed across the boundary line between Morris and Sussex Counties. Consequently, it is located in Mount Olive Township, Morris County, New Jersey and Byram Township, Sussex County, New Jersey. Principal access to the dam is by the local roads of Waterloo Village, an historical site consisting of restored buildings of the colonial era.

c. Size and Hazard Classification

Size and Hazard Classification criteria presented in "Recommended Guidelines for Safety Inspection of Dams", published by the U.S. Army Corps of Engineers are as follows:

SIZE CLASSIFICATION

	Impoundment	
Category	Storage (Ac-ft)	Height (Ft)
Small	< 1000 and ≥ 50	< 40 and ≥ 25
Intermediate	≥ 1000 and $< 50,000$	≥ 40 and < 100
Large	$\geq 50,000$	≥ 100

HAZARD POTENTIAL CLASSIFICATION

Category	Loss of Life (Extent of Development)	Economic Loss (Extent of Development)
Low	None expected (no permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agriculture)
Significant	Few (No urban developments and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry or structures)
High	More than few	Excessive (Extensive community, industry or agriculture)

The following characteristics relating to size and downstream hazard for Lake Waterloo Dam have been obtained for this Phase I assessment:

Storage: 113 acre-feet

Height: 8.7 feet

Potential Loss of Life:

Two buildings of Waterloo Village are located along the Musconetcong River within 1200 feet of the dam in the SDF flood plain. Although they are uninhabited, the two buildings are open to tours. Several other buildings of Waterloo Village, some of which are inhabited, are located along the Musconetcong River at elevations at least 5 feet higher than the elevation of the crest of dam.

A Route I-80 bridge crosses the Musconetcong River approximately 2500 feet downstream from the dam.

Potential Economic Loss:

Two buildings of Waterloo Village located in the SDF flood plain could sustain some damage as a result of dam failure. The Route I-80 bridge would probably not sustain severe damage as a result of dam failure.

Therefore, Lake Waterloo Dam is classified as "Small" size and "Significant" hazard potential.

d. Ownership

Lake Waterloo Dam is owned by the State of New Jersey and leased to Waterloo Foundation for the Arts, Stanhope, N.J. 07874. Waterloo Foundation for the Arts operates Waterloo Village.

e. Purpose

The purpose of the dam is the impoundment of a recreational lake.

f. Design and Construction History

Reportedly, the dam was constructed in 1919 as a mill dam. No information regarding the design of the dam is available.

g. Normal Operational Procedures

The dam and appurtenances are maintained by the maintenance staff of Waterloo Village. There is no fixed schedule of maintenance; repairs are made as the need arises.

Reportedly, the lake is never lowered although the elevations of the gates on the west and south sides of the outlet works are adjusted ocasionally.

1.3 Pertinent Data

a.	Drainage Area	62.4 square miles

b. Discharge at Damsite

Maximum known flood at damsite	2295 c.f.s., Feb. 6, 1896 and 2170 c.f.s. Aug. 19, 1955 recorded at Saxon Falls 3 miles downstream from dam.
Outlet works at normal pool elevation	292 c.f.s.
Spillway capacity at top of dam	538 c.f.s.
Outlet works functioning as auxiliary spillway at top of dam	51 c.f.s.
Total spillway capacity at top of dam	589 c.f.s.

c. Elevation (Feet above MSL)

Top of Dam	649.8
Maximum pool-design surcharge	650.7
Full flood control pool	N.A.
Recreation pool	648.7
Spillway crest	648.0
Stream bed at toe of dam	641.1
Maximum tailwater	649 (Estimated)

d. Reservoir

Length of maximum pool	2,300 feet (Estimated)
Length of recreation pool	2,200 feet (scaled)
Length of flood control pool	N.A.

e. Storage (Acre-feet)

Recreation pool	68 acre-feet
Flood control pool	N.A.
Maximum pool	158 acre-feet
Top of dam	113 acre-feet

f. Reservoir Surface (acres)

Top of dam	45.6 acres (Estimated)
Maximum pool	53 acres (Estimated)
Flood control pool	N.A.
Recreation pool	36.0 acres
Spillway crest	30.0 acres

g. Dam

Type	Earthfill
Length	496 feet
Hydraulic height	8.7 feet
Side slopes - Upstream	5 horiz. to 1 vert.
- Downstream	2 horiz. to 3 vert.
Zoning	Unknown
Impervious core	Unknown
Cutoff	Unknown
Grout curtain	Unknown

h. Diversion and Regulating Tunnel — N.A.

i. Spillway

Type	Concrete weir
Length of weir	76 feet
Crest elevation	648.0
Gates	None
Upstream channel	N.A.
Downstream channel	Wide section of Musconetcong River between subject dam and downstream concrete dam

j. Regulating Outlets

Stoplogs 8.7 feet long in concrete box structure constructed across raceway at north end of dam.

SECTION 2: ENGINEERING DATA

2.1 Design

No information relating to the design of the subject dam is available. The only apparent reference to the dam is contained in an inspection report obtained from the files of the NJDEP. The report, written in 1930 by the State Water Policy Commission in connection with a proposed dam (apparently never constructed), referred to "the old Waterloo mill dam."

In addition, a summary of boring logs describing subsurface conditions at a proposed dam site 0.4 miles downstream from the subject dam is available. The summary, which is contained in the inspection report mentioned above, describes the site 0.4 miles downstream from the subject dam, in part, as lying in a valley filled with glacial till with no outcrops of bedrock visible near the site.

2.2 Construction

No data nor reports pertaining to the construction of the dam are available.

2.3 Operation

No records of the operation of the lake or dam are available.

2.4 Evaluation

a. Availability

Engineering information pertaining to the subject dam is not available. Information contained in the NJDEP files for "Lake Waterloo Dam" pertains to a dam proposed to be constructed in 1930 at a location 0.4 miles downstream from the subject dam. That proposed dam apparently was not constructed.

b. Adequacy

Available engineering data pertaining to Lake Waterloo Dam are not adequate to be of significant assistance in the performance of a Phase I evaluation. A list of absent information is included in paragraph 7.1.b.

c. Validity

The validity of engineering data cannot be assessed due to the absence of data.

SECTION 3: VISUAL INSPECTION

3.1 Findings

a. General

The inspections of Lake Waterloo Dam were performed on May 1, 1979 and July 13, 1979 by staff members of Storch Engineers. A copy of the visual inspection check list is contained in Appendix 1. The following procedures were employed for the inspection:

1. The embankment of the dam, appurtenant structures and adjacent areas were examined.
2. The embankment and accessible appurtenant structures were measured and key elevations determined with the use of a surveyor's level.
3. The embankment, appurtenant structures and adjacent areas were photographed.

b. Dam

The vertical alignment of the embankment is generally level with some slight variations in crest elevation. The embankment is generally grass covered with a footpath worn on the crest in some areas. Also, a few trees are located on the embankment. An eroded section is present on the downstream side of embankment approximately 30 feet north of the spillway. However, riprap on the downstream face at this location is intact. A repaired breach section is located approximately 30 feet south of the spillway. The section is 10 feet wide and extends across the full width of the embankment and appears to be filled with

rocks and soil. A section of the dam adjacent to the north end of the spillway on the downstream side of embankment, was in a partially washed out condition at the time of inspection.

Riprap on the downstream face of embankment appeared to be in generally good condition. Riprap on the upstream face of embankment near the south end of dam appeared to be providing generally inadequate slope protection.

A fault is located beneath the dam site oriented along the bed of the Musconetcong River. The fault comprises the contact plane between two distinct bedrock formations underlying the site - Byram gneiss lying to the north (in Sussex County) and Kittatinny limestone to the south (in Morris County). Overlying the gneissic bedrock is glacial stratified drift deposited by melt waters flowing from the Wisconsin glacier composed of assorted, relatively homogeneous materials consisting predominantly of sand and gravel, with some silt and clay in depressions. Overlying the limestone is glacial ground moraine composed of unstratified material deposited during the Wisconsin glaciation composed of unassorted, heterogeneous intermixed soil fractions ranging in size from clay to boulders, with silt predominant. Overlying the glacial drift and glacial moraine is recent alluvium composed of stratified materials deposited by streams.

c. Appurtenant Structures

The crest and downstream face of the spillway are in generally adequate condition along their southern portions but are deteriorated near their north ends. The elevation of the crest is slightly higher near its north end so that spillway discharge does not overtop the north end during low flow periods. The timbers comprising the downstream face are

severely rotted near the north end. The stone masonry training walls at the north and south ends of the spillway are in fair condition.

Most of the concrete surfaces of the outlet works are generally in satisfactory condition. Some spalling and exposed aggregate was noted on the inside of the chamber and significant spalling was noted on the downstream wingwalls. The stoplogs appeared to be in generally adequate condition although they were submerged by overflow at the time of inspection.

d. Reservoir Area

Lake Waterloo is an irregularly shaped lake with a length of approximately 2200 feet. The area around the lake is wooded and no structures were observed along the shoreline. Shore slopes range from 5 percent to 20 percent with an average slope of approximately 10 percent.

e. Downstream Channel

Discharge from the spillway enters directly into the Musconetcong River which is approximately 200 feet wide in the area between the dam and a concrete dam located 1000 feet downstream. This wide portion of the river is generally free of obstructions and has steep banks with an average slope of 25 percent.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures

The level of water in Lake Waterloo is regulated naturally by discharge over the spillway and stoplogs of the outlet works of the dam. Reportedly, the lake is not lowered for any purpose.

The stoplogs in the outlet works can be removed to lower the lake and the estimated time required to lower the lake to the invert of the stoplogs is one day.

4.2 Maintenance of the Dam

There is no program of regular inspection and maintenance of the dam and appurtenant structures. Maintenance is performed by the maintenance staff of Waterloo Village on an "as needed" basis.

The most recent maintenance was the filling of the breach section of the embankment adjacent to the north end of the spillway about two years ago. Subsequent to that repair, the section has again partially washed out. Other maintenance was performed about four years ago when a breach section in the south section of the embankment was filled with rocks and earth.

4.3 Maintenance of Operating Facilities

Maintenance of operating facilities is performed on an "as needed" basis. It is not known when the most recent maintenance was performed.

4.4 Description of Warning System

Reportedly, there is no warning system in use at the present time.

4.5 Evaluation of Operational Adequacy

The operation of the dam has been unsatisfactory in that it has been overtopped and has breached at least twice in recent years.

Maintenance documentation is poor and the maintenance program for the dam appears to be insufficient in the following areas:

1. Trees on embankment not removed.
2. Deteriorated condition of spillway not corrected.
3. Partial washout adjacent to north end of spillway not repaired.
4. Spalling of concrete in outlet works not repaired.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design Data

The quantity of storm water runoff that the spillway should be able to pass without an overtopping of the dam is based on the size and hazard classification of the dam. This runoff, called the spillway design flood (SDF) is described in terms of return frequency or probable maximum flood (PMF) depending on the extent of the dam's size and potential hazard. According to the "Recommended Guidelines for Safety Inspection of Dams" published by the U.S. Army Corps of Engineers, the SDF for Lake Waterloo Dam falls in a range of 100-year frequency to 1/2 PMF. In this case, the low end of the range, 100-year frequency, is chosen since the factors used to select size and hazard classification are on the low side of their respective ranges.

The SDF peak computed for Lake Waterloo Dam is 2165 c.f.s. This value was determined by adjusting the 100-year peak flow for the Musconetcong River at Saxon Falls, three miles downstream from the dam. The magnitude of the 100-year peak flow at Saxon Falls was supplied by the U.S. Army Corps of Engineers. The SDF inflow hydrograph for Lake Waterloo Dam was then computed by adjusting the PMF hydrograph supplied by the Corps of Engineers.

The spillway and outlet works discharge rates were computed by the use of weir formulas appropriate for the configurations of their overflow sections. (See Appendix 4.) The total spillway discharge with lake level equal to the top of dam was computed to be 589 c.f.s.

The SDF was routed through the dam by use of the HEC-1-DB computer program using the modified Puls method. In routing the SDF, it was found that the dam crest would be overtopped by a depth of 0.9 feet. Accordingly, the subject spillway is assessed as being inadequate in accordance with criteria developed by the U.S. Army Corps of Engineers.

b. Experience Data

Reportedly, the dam has been overtopped at least twice in recent years. Breaches of the embankment resulted from each of those overtoppings.

c. Visual Observation

Evidence of the two breach sections referred to above were observed at the time of inspection. In addition, an eroded area on the downstream side of the embankment, which appeared to be the result of flow over the dam, was observed. Also, the condition of the grass on the crest of embankment indicated the possibility of a recent overtopping.

d. Overtopping Potential

As indicated in paragraph 5.1.a, a storm of magnitude equal to the SDF would cause overtopping of the dam to a height of 0.9 foot in a non-breach condition. The spillway is capable of passing approximately 27 percent of the SDF with lake level equal to the crest of dam.

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

The embankment appeared, at the time of inspection, to be generally outwardly stable, with one partial washout adjacent to the spillway and one eroded area on the downstream side of the embankment noted. In addition, distress (in the form of rotted timbers on the downstream face) was noted in the north end of the spillway.

b. Design and Construction Data

Analysis of structural stability and construction data for the embankment and spillway structure are not available.

c. Operating Records

No operating records for the dam are available. The water level of Lake Waterloo is not monitored.

d. Post Construction Changes

Records of post construction changes to the dam or area around the dam are not available.

e. Seismic Stability

Lake Waterloo Dam is located in Seismic Zone 1 as defined in "Recommended Guidelines for Safety Inspection of Dams" which is a zone of very low seismic activity. Experience indicates

that dams in Seismic Zone 1 will have adequate stability under seismic loading conditions if stable under static loading conditions. Lake Waterloo Dam appeared to be generally stable under static loading conditions at the time of inspection.

Records at the Lamont-Doherty Geological Observatory of Columbia University indicate that no recent detectable earthquakes have occurred in the vicinity of the dam site.

SECTION 7: ASSESSMENT AND RECOMMENDATIONS

7.1 Dam Assessment

a. Safety

Based on hydraulic and hydrologic analyses outlined in Section 5 and Appendix 4, the spillway of Lake Waterloo Dam is assessed as being inadequate. The spillway and outlet gate are not able to pass the SDF without an overtopping of the dam.

The embankment appeared, at the time of inspection, to be generally stable, with one partial washout adjacent to the spillway and one eroded area on the downstream side of the embankment noted. In addition, distress (in the form of rotted timbers on the downstream face) was noted in the north end of the spillway

b. Adequacy of Information

Information sources for this report include: 1) field inspection, 2) USGS quadrangle, 3) aerial photograph from Morris County, 4) aerial topography from Mt. Olive Township and 5) consultation with maintenance personnel of Waterloo Village.

The information obtained is sufficient to allow a Phase I assessment as outlined in "Recommended Guidelines for Safety Inspection of Dams."

Some of the absent data are as follows:

1. Construction and as-built drawings.
2. Description of fill material for embankment.
3. Design computations and reports.
4. Maintenance documentation.
5. Soils report for the site.

c. Necessity for Additional Data/Evaluation

Although some data pertaining to Lake Waterloo Dam are not available, additional data are not considered imperative for this Phase I evaluation.

7.2 Recommendations

a. Remedial Measures

Based on hydraulic and hydrologic analyses outlined in paragraph 5.1.a, the spillway is considered to be inadequate. It is therefore recommended that a professional engineer experienced in the design and construction of dams be engaged in the near future to perform more detailed hydraulic and hydrologic analyses relating to the spillway capacity. The analyses should more accurately determine runoff characteristics of the watershed and should refine the discharge capacity of the spillway and the downstream channel capacity. Based on the findings of these analyses, the need for and type of mitigating measures should be determined and then implemented.

In addition, it is recommended that a professional engineer experienced in the design and construction of dams be engaged in the near future to investigate the repairs made at the breach locations and to determine their adequacy and prepare a detailed design for embankment improvements, including any necessary filling, regrading and riprap, and the embankment should be renovated accordingly. This remedial work should include a complete inspection and renovation of the spillway.

It is further recommended that the following remedial measures be undertaken by the owner in the near future.

1) Trees on the embankment should be removed.

2) The outlet works should be renovated by patching deteriorated concrete and coating with an epoxy sealant. Also the timber stoplogs should be thoroughly inspected and replaced if necessary.

b. Maintenance

The owner of the dam should initiate, in the near future, a program of periodic inspection and maintenance, the complete records of which to be kept on file and made available to the public. A visual inspection of the dam and appurtenances by a professional engineer experienced in the design and construction of dams should be made annually and reported on a standardized check-list form. Repairs should be made as required and the following maintenance should be performed annually: remove adverse vegetation from the embankment, fill and sod any eroded surfaces of the embankment and repair riprap. In addition, the lake should be lowered at least once every five

years at which time the lake should be cleaned and the normally submerged portions of the dam and spillway inspected and repaired.

c. Additional Studies

A detailed topographic survey of the dam and area around the dam based on USGS datum should be undertaken by a qualified licensed land surveyor or professional engineer in the near future. The survey map should become part of the permanent record mentioned in paragraph 7.2.b.

PLATES

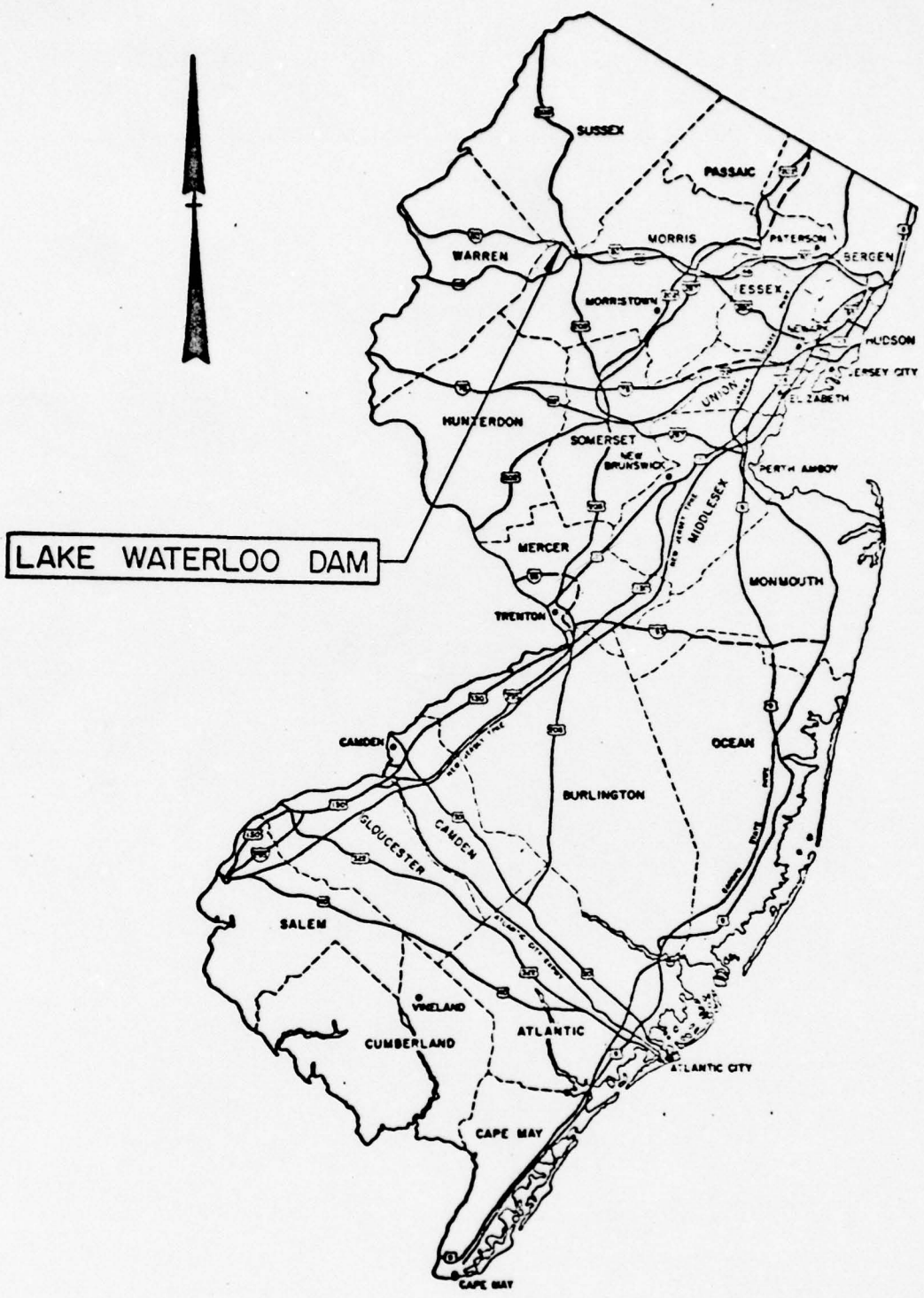


PLATE 1

STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	INSPECTION AND EVALUATION OF DAMS KEY MAP LAKE WATERLOO DAM
DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY	I.D. NJ00276 / SCALE: NOT TO SCALE DATE: JUNE, 1979

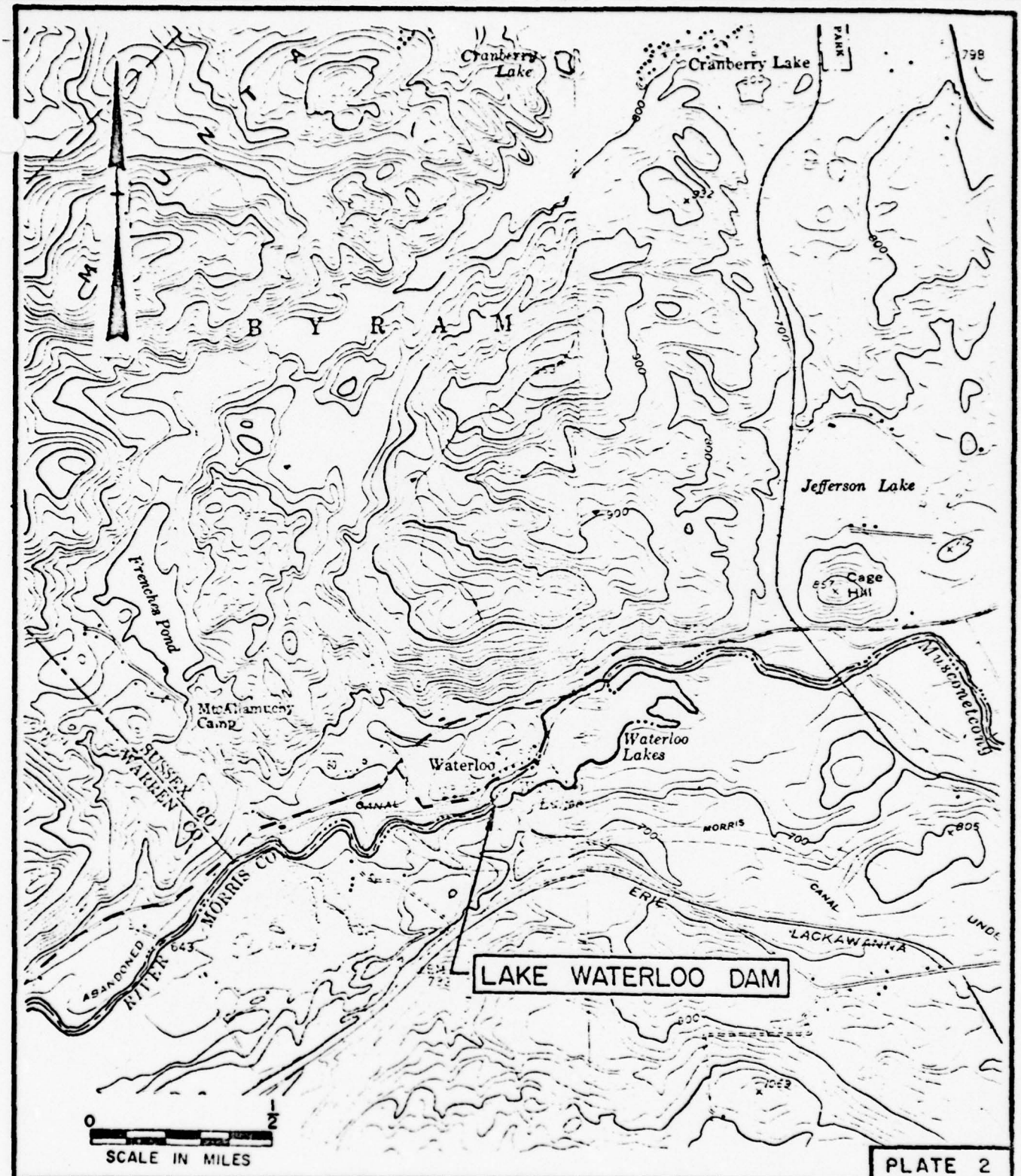


PLATE 2

STORCH ENGINEERS
FLORHAM PARK, NEW JERSEY

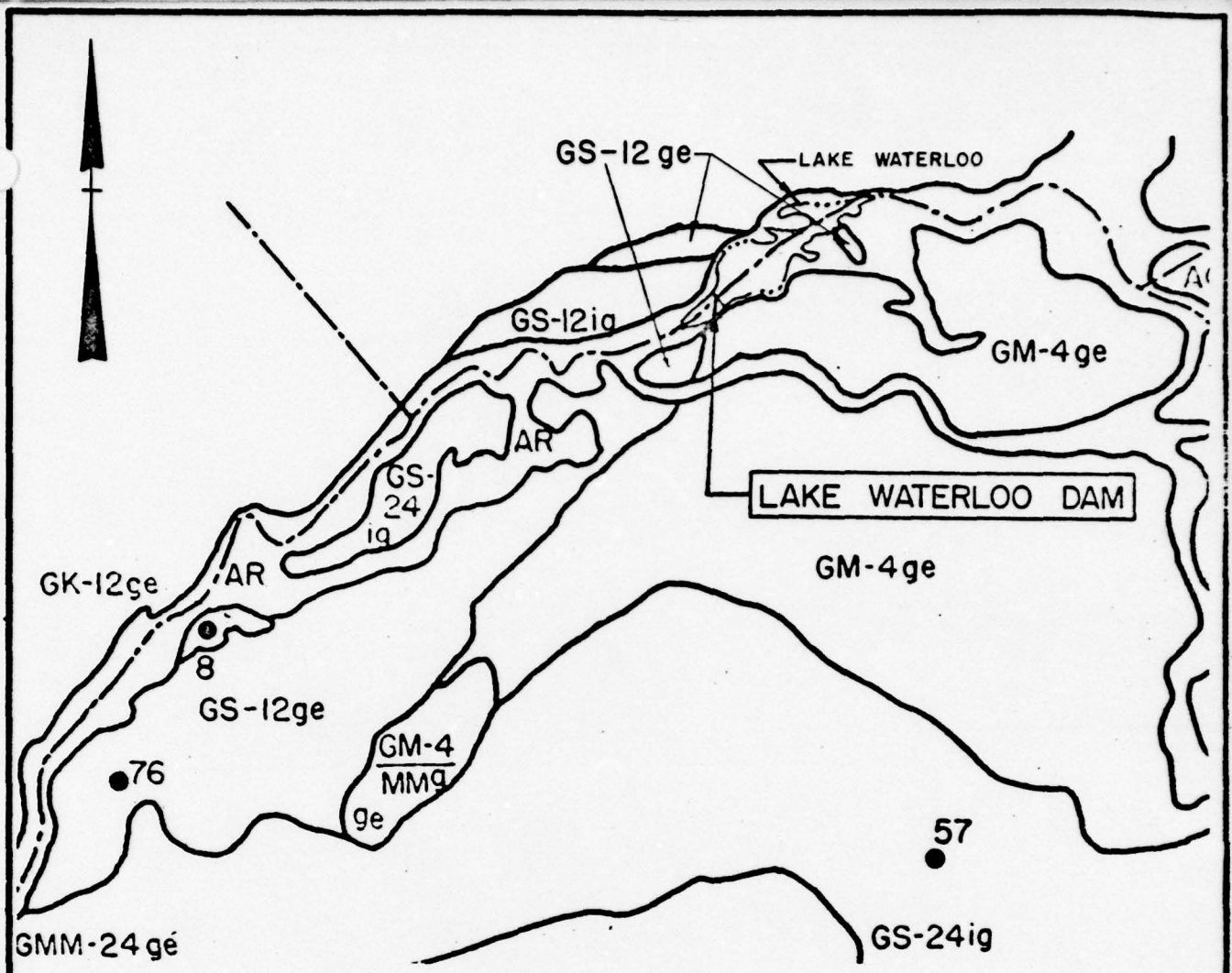
DIVISION OF WATER RESOURCES
N.J. DEPT. OF ENVIR. PROTECTION
TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

VICINITY MAP

LAKE WATERLOO DAM

I.D. NJ 00276	SCALE: AS SHOWN
	DATE: JUNE, 1979



Legend

AR	Recent alluvium composed of stratified materials deposited by streams.
GM-4	Glacial ground moraine composed of unstratified material deposited during the Wisconsin glaciation overlying Kittatinny limestone.
GS-12	Glacial stratified drift deposited by melt waters flowing from the Wisconsin glacier overlying Byram gneiss.

NOTE: Information taken from Rutgers University Soil Survey of New Jersey, Report No. 9, Morris County and Report No. 11, Sussex County, and from Geologic Map of New Jersey prepared by Lewis and Kummel.

PLATE 3

STORCH ENGINEERS
FLORHAM PARK, NEW JERSEY

DIVISION OF WATER RESOURCES
N.J. DEPT. OF ENVIR. PROTECTION
TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

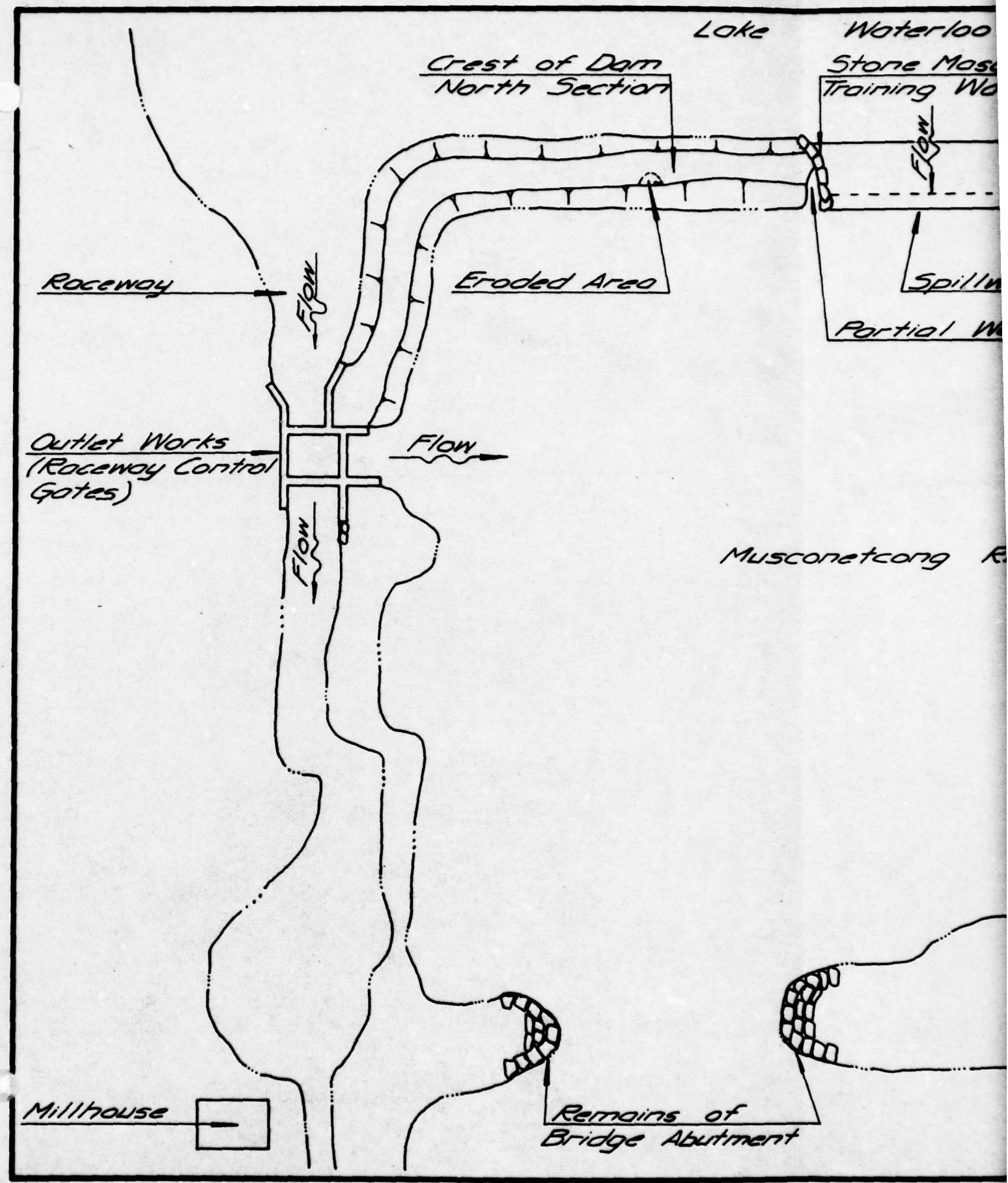
SOIL MAP

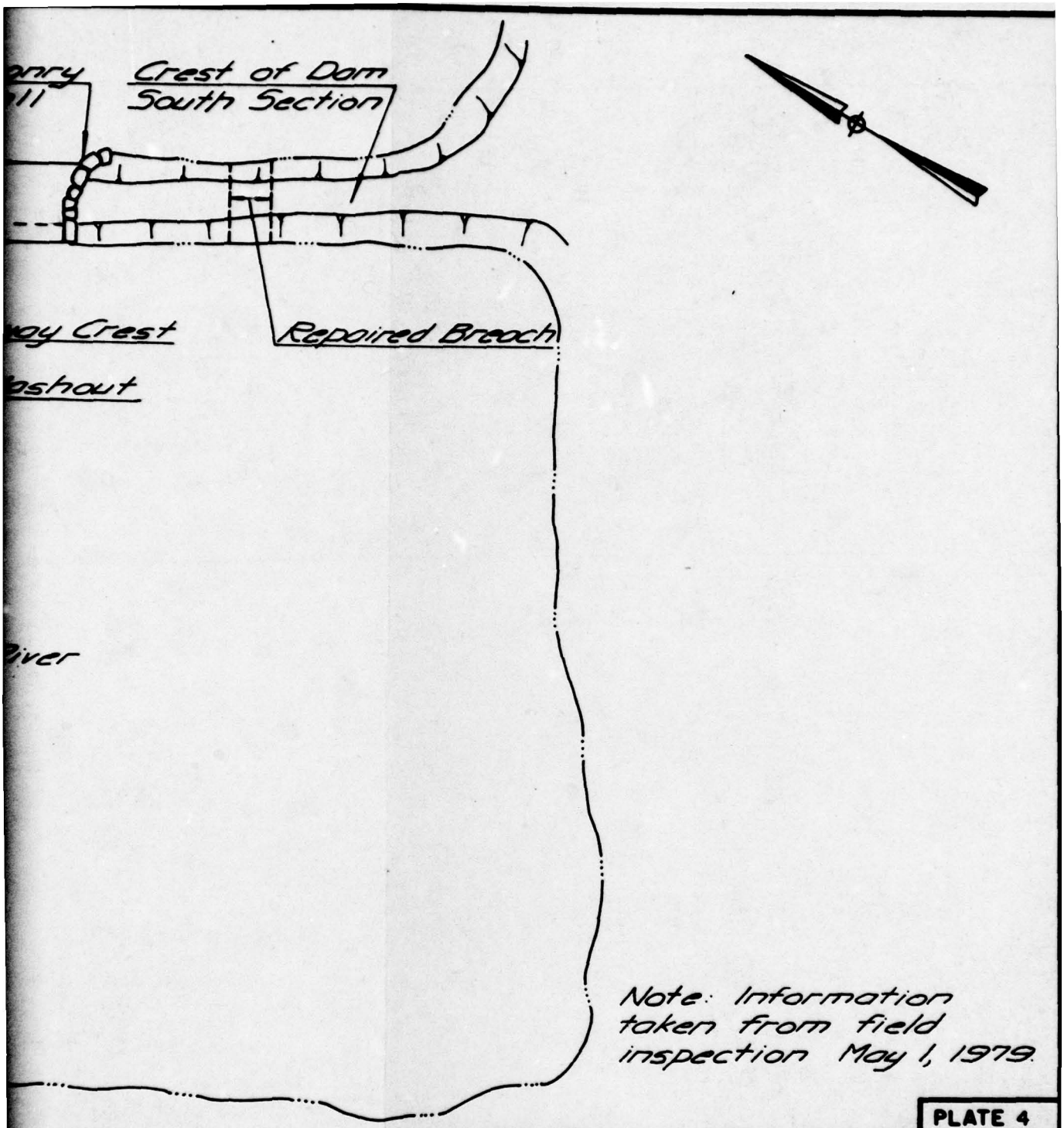
LAKE WATERLOO DAM

I.D. NJ00276

SCALE: NONE

DATE: JULY, 1979


Lake
Crest of Dam
North Section
Stone Mas
Training Wo
Flow
Raceway
Flow
Eroded Area
Spillw
Partial W
Outlet Works
(Raceway Control
Gates)
Flow
Flow
Musconetcong R
Millhouse
Remains of
Bridge Abutment



Note: Information taken from field inspection May 1, 1979.

PLATE 4

STORCH ENGINEERS
FLORHAM PARK, NEW JERSEY

DIVISION OF WATER RESOURCES
N.J. DEPT. OF ENVIR. PROTECTION
TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

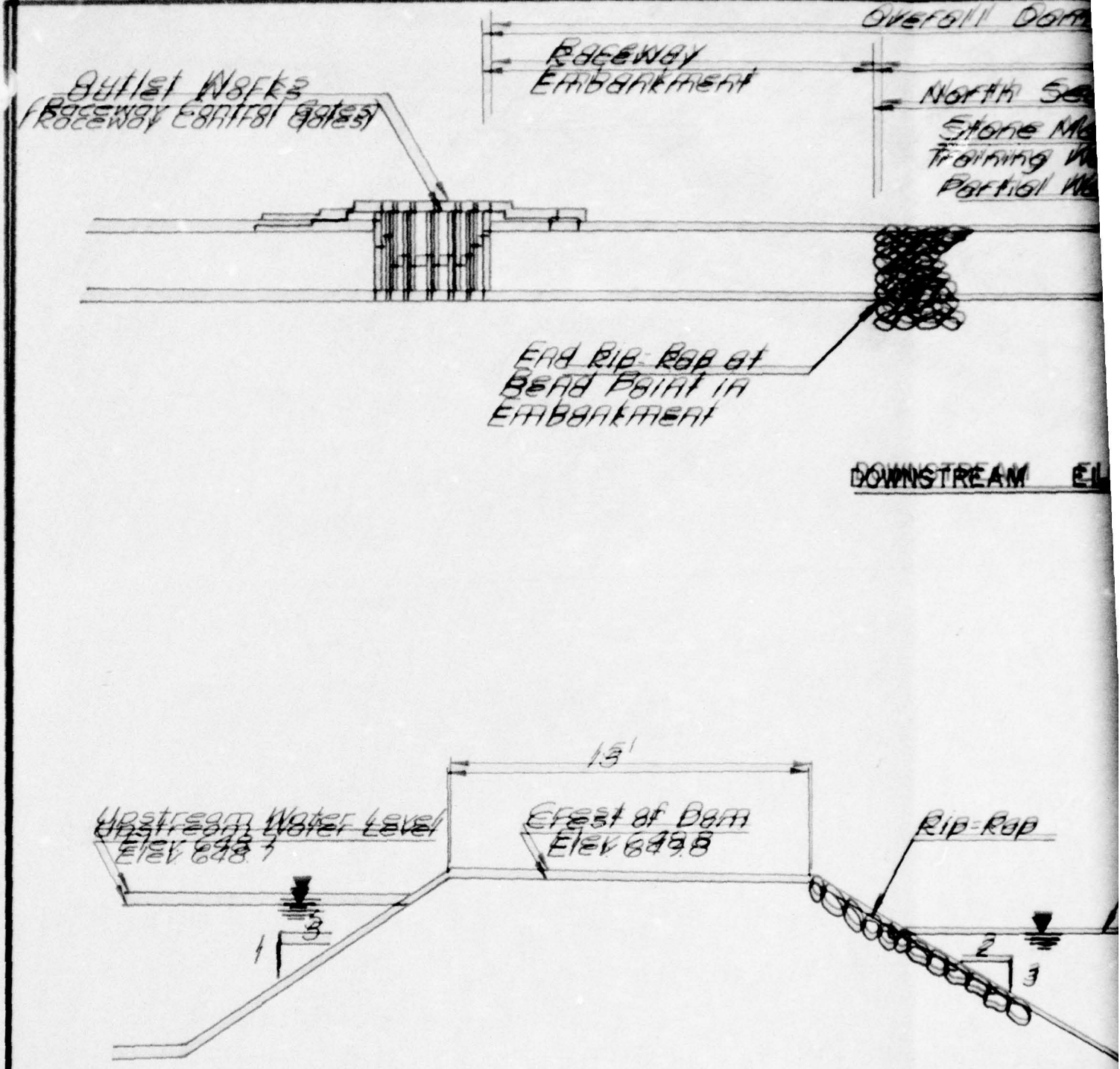
GENERAL PLAN

LAKE WATERLOO DAM

I.D. N.J. [redacted]

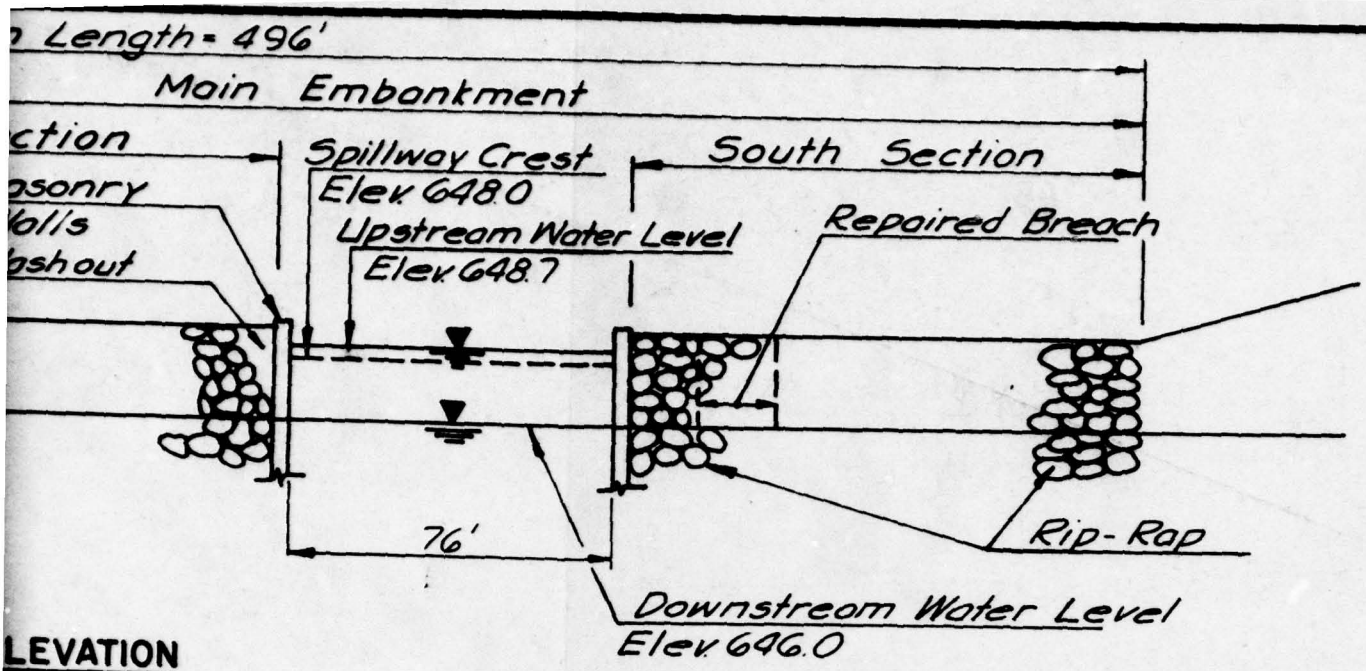
SCALE: NOT TO SCALE

DATE: JULY, 1979



DAM SECTION

Note: Information taken from field inspection May 1, 1979



LEVATION

Downstream Water Level
Elev. 646.0

PLATE 5

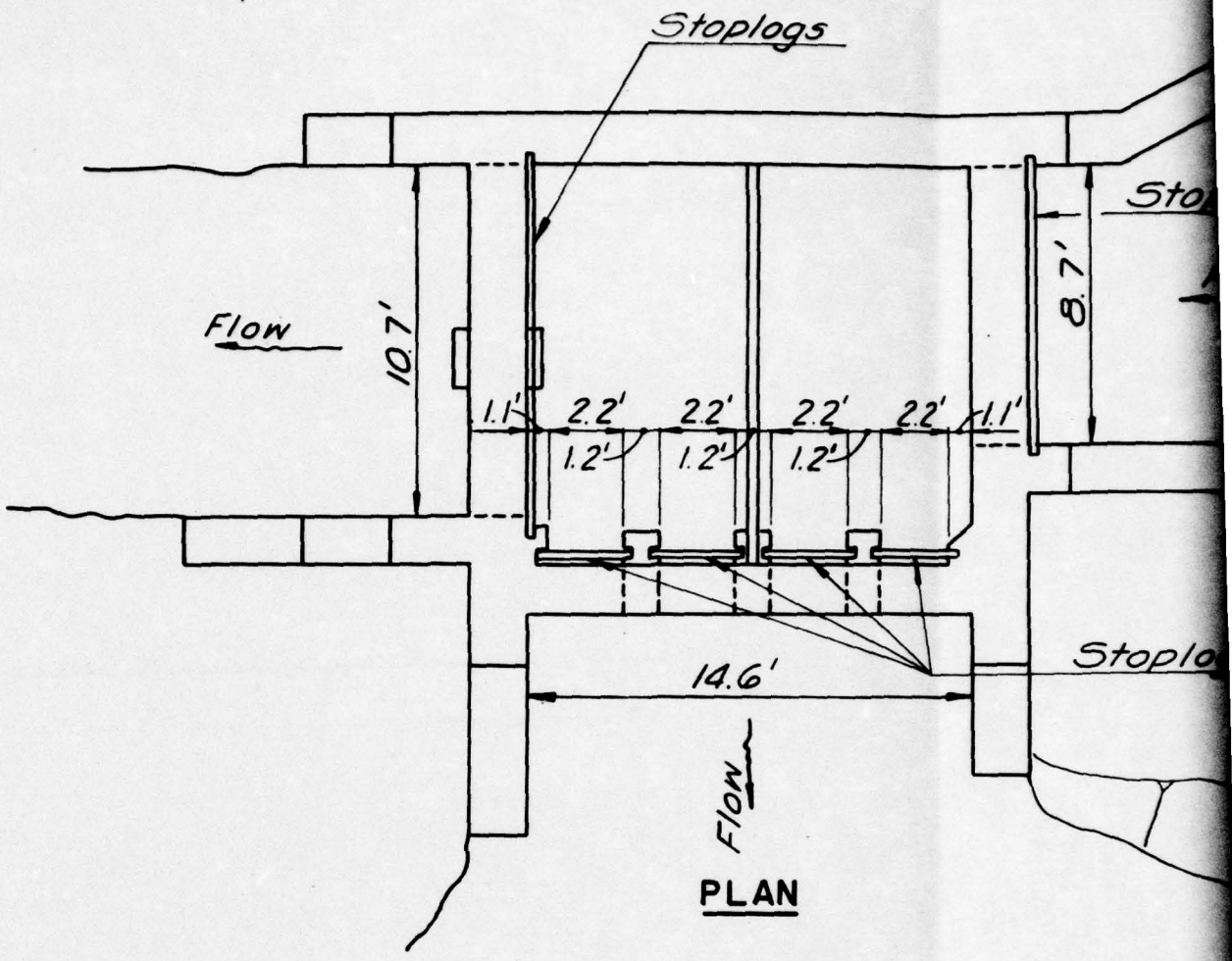
STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

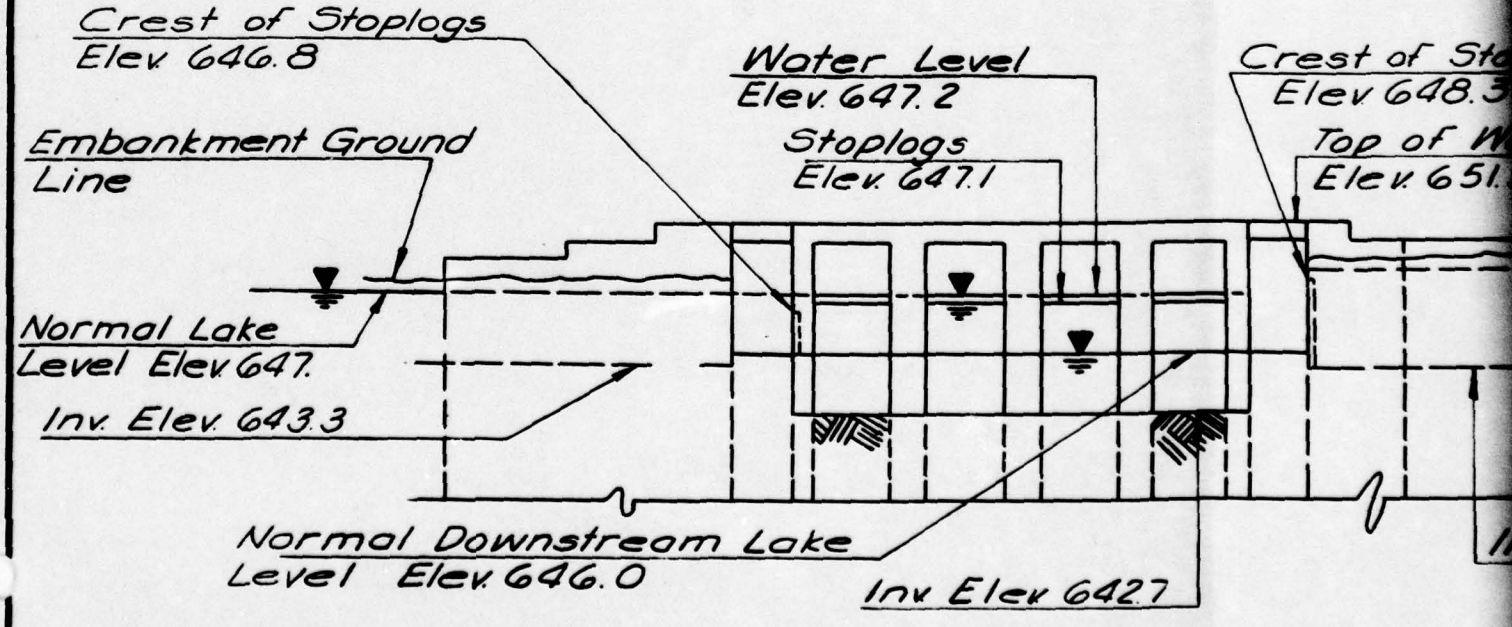
ELEVATION & SECTION

LAKE WATERLOO DAM

I.D. NJ00276	SCALE: NOT TO SCALE



PLAN



Note: Information taken from field inspection May 1, 1979.

ELEVATION

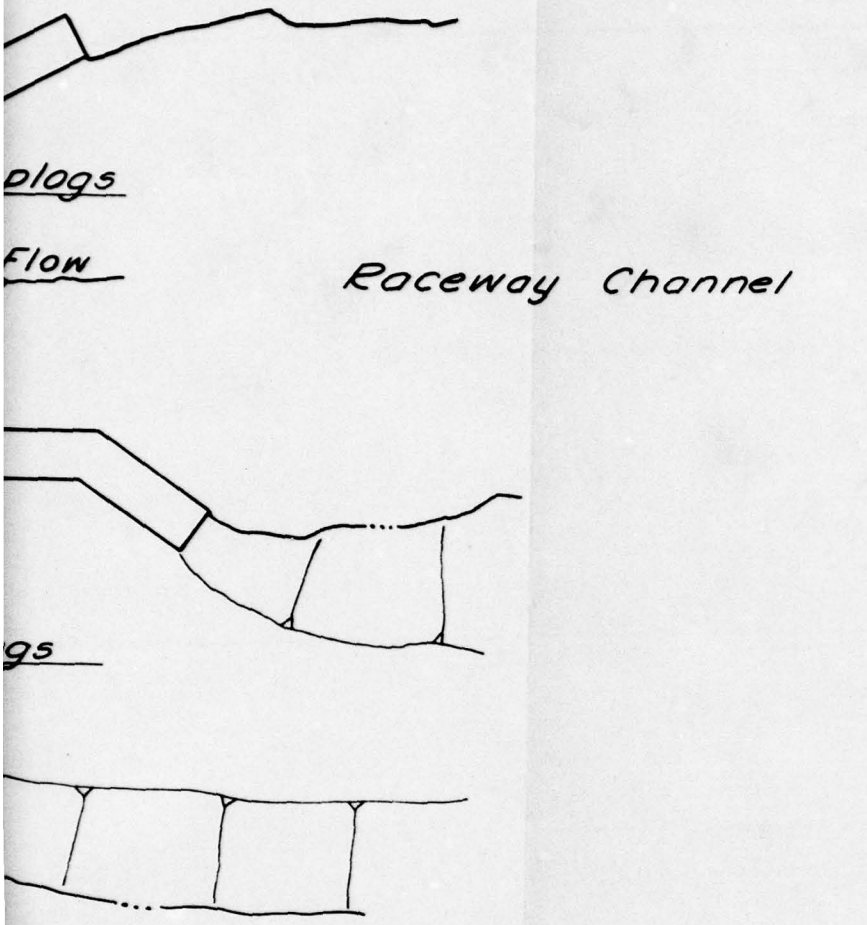


PLATE 6

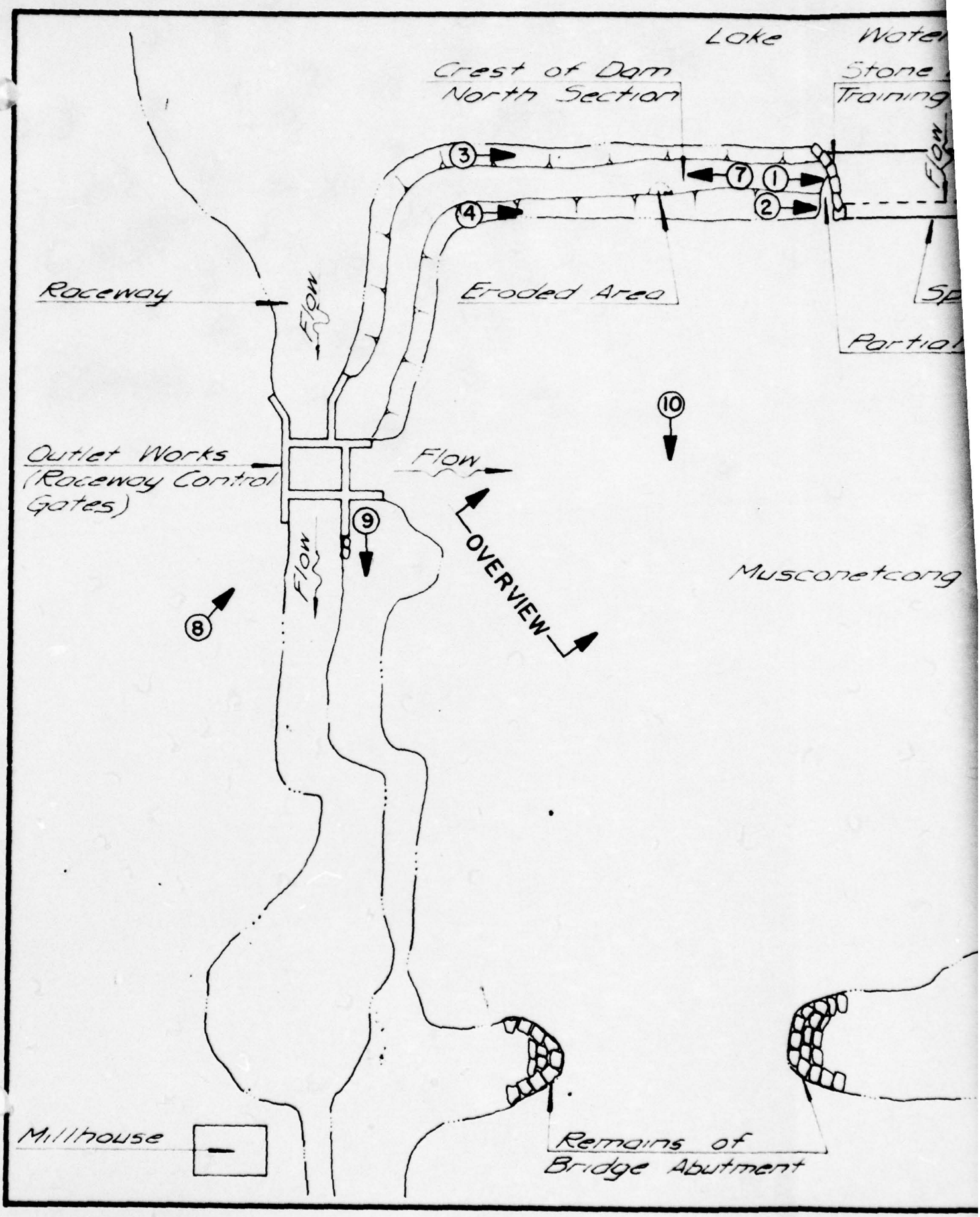
STORCH ENGINEERS FLORHAM PARK, NEW JERSEY	DIVISION OF WATER RESOURCES N.J. DEPT. OF ENVIR. PROTECTION TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

OUTLET WORKS

LAKE WATERLOO DAM

I.D. NJ00276	SCALE: NOT TO SCALE
	DATE: JUNE, 1979


Lake
Crest of Dam
North Section
Stone
Training
Flow
3
7
1
2
4
Raceway
Flow
Eroded Area
Sp
Partial
10
Outlet Works
(Raceway Control
Gates)
Flow
9
Flow
OVERVIEW
Musconetcong
8
Millhouse
Remains of
Bridge Abutment

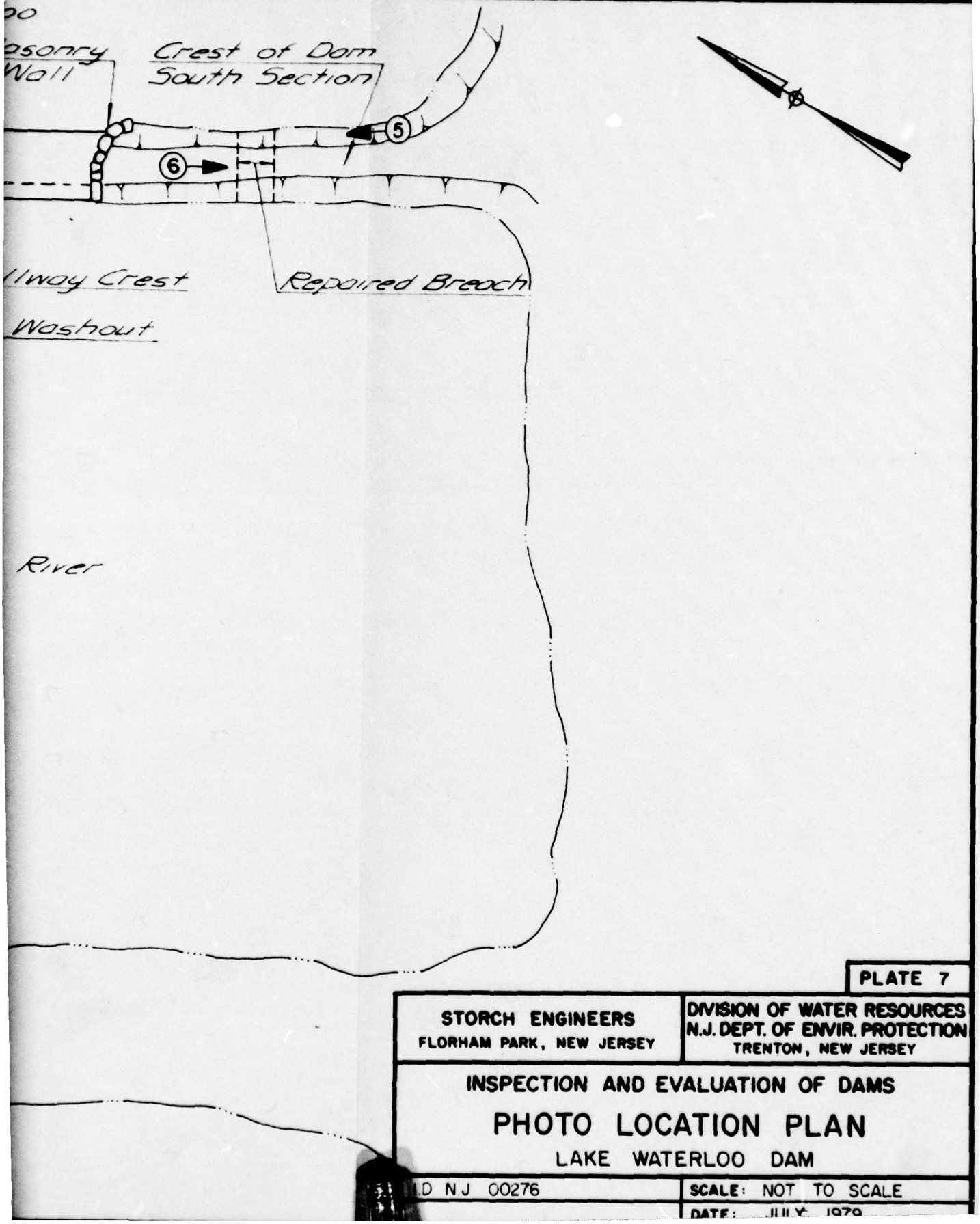


PLATE 7

STORCH ENGINEERS
FLORHAM PARK, NEW JERSEY

DIVISION OF WATER RESOURCES
N.J. DEPT. OF ENVIR. PROTECTION
TRENTON, NEW JERSEY

INSPECTION AND EVALUATION OF DAMS

PHOTO LOCATION PLAN

LAKE WATERLOO DAM

I.D N J 00276

SCALE: NOT TO SCALE

DATE: JULY 1979

APPENDIX 1

Check List - Visual Inspection

Check List - Engineering Data

Check List
Visual Inspection
Phase I

Name of Dam Lake Waterloo County Morris/Sussex State New Jersey Coordinators NJDEP

Date(s) Inspection 5/1/79
7/13/79 Weather Fair Temperature 60°F

Pool Elevation at Time of Inspection 648.7 M.S.L. Tailwater at Time of Inspection 646.0 M.S.L.

Inspection Personnel:

John Gribbin David Hoyt Allan Volle

Ronald Lai Joseph Fox

Richard McDermott

John Gribbin Recorder

Present: Bert Pagano, maintenance staff, Waterloo Village

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
GENERAL	N.A.	
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	N.A.	
DRAINS	N.A.	
WATER PASSAGES	N.A.	
FOUNDATION	N.A.	
VERTICAL AND HORIZONTAL ALIGNMENT	N.A.	

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	N.A.	
STRUCTURAL CRACKING	N.A.	
CONSTRUCTION JOINTS	N.A.	
MONOLITH JOINTS	N.A.	
LEAKAGE	N.A.	
SEEPAGE	N.A.	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
GENERAL	Embankment generally grass covered with some trees. Foot path worn along crest of embankment along race-way.	
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	Partial washout of embankment adjacent to north end of spillway.	
ANY NOTICEABLE SEEPAGE	Unknown. Observation not possible.	Entire downstream toe of dam submerged.
STAFF GAGE AND RECORDER	None	
DRAINS	None	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None observed.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None observed.	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	Erosion observed on downstream side of north section of embankment. Evidence of repair of breach in south section of embankment. Breach filled with earth and rocks.	Recommend investigation of adequacy of repairs.
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	Vertical: generally level Horizontal: straight sections with 90-degree bend.	
RIPRAP FAILURES	Riprap along downstream face of embankment in generally good condition. No riprap observed along upstream slope of north section of dam. Riprap observed along upstream slope of south section of dam was sparse and generally inadequate.	Recommend design for additional riprap.

OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SURFACES IN OUTLET CONDUIT	Condition of concrete generally satisfactory for most of the structure. Some spalling and exposed aggregate on the inside of chamber. Significant spalling on downstream wingwalls.	Raceway control gates serve as outlet works.
INTAKE STRUCTURE	Submerged.	Consists of stoplogs at upstream (east) end of outlet works.
OUTLET STRUCTURE	Submerged.	Consists of stoplogs at west and at south sides of outlet works.
OUTLET CHANNEL	Outlet works outlet into downstream channel and into mill race.	
GATE AND GATE HOUSING	Intake and outlet stoplogs submerged by discharge but appeared to be in adequate condition.	

SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CREST	Spillway crest is aligned straight and level for most of its length. A section near the north end is irregular due to deterioration. A few large rocks are located along the irregular section of the crest. The timbers in the downstream face are severely rotted near the north end.	Downstream face is composed of timber wall. Crest is composed of concrete slab.
TRAINING WALLS	Stone masonry walls on concrete foundations appear to be in fair condition.	
APPROACH CHANNEL	N.A.	
DISCHARGE CHANNEL	Spillway discharges directly into downstream channel (Musconetcong River).	

INSTRUMENTATION

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None	
OBSERVATION WELLS	None	
WEIRS	None	
PIEZOMETERS	None	
OTHER	N.A.	

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Shore slopes range from 5% to 20% with an average slope of approx. 10%.	
SEDIMENTATION	Unknown	
STRUCTURES ALONG BANKS	No structures were observed along the lake banks. Buildings associated with Waterloo Village are situated along the north bank of the raceway.	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	Downstream channel (Musconetcong River) is a 200-ft. wide stream in the vicinity of the dam and has no significant obstructions.	
SLOPES	The banks are steep with an average slope of approx. 25%.	
STRUCTURES ALONG BANKS	Approx. 2 buildings associated with Waterloo Village are located along the north bank of the downstream channel within 1000 feet of the dam. A concrete dam is located 1000' downstream from subject dam. Route I-80 bridge 2500' downstream from subject dam.	

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
DAM - PLAN	Not Available
SECTIONS	Not Available
SPILLWAY - PLAN	Not Available
SECTIONS	Not Available
DETAILS	Not Available
OPERATING EQUIPMENT PLANS & DETAILS	Not Available
OUTLETS - PLAN	
DETAILS	
CONSTRAINTS	Not Available
DISCHARGE RATINGS	
HYDRAULIC/HYDROLOGIC DATA	Stream gaging records available. USGS gaging station 1-4560.00.
RAINFALL/RESERVOIR RECORDS	Not Available
CONSTRUCTION HISTORY	Not Available
LOCATION MAP	Available

ITEM	REMARKS
DESIGN REPORTS	Not Available
GEOLOGY REPORTS	Not Available
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	Not Available
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	Soil description in inspection report for site 0.4 miles downstream from subject dam. (NJDEP file).
POST-CONSTRUCTION SURVEYS OF DAM	Not Available
BORROW SOURCES	Not Available

ITEM	REMARKS
MONITORING SYSTEMS	Not Available
MODIFICATIONS	Not Available
HIGH POOL RECORDS	Not Available
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Not Available
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	Not Available
MAINTENANCE OPERATION RECORDS	Not Available

APPENDIX 2

Photographs

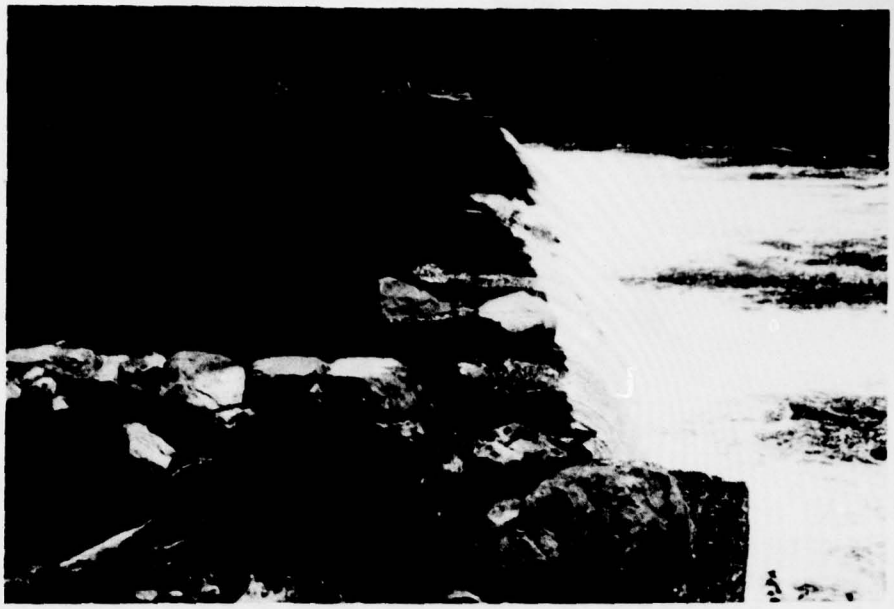


PHOTO 1

SPILLWAY

PHOTO 2

WASHOUT ADJACENT TO NORTH END OF SPILLWAY

LAKE WATERLOO DAM
1 MAY 1979

PHOTO 3

UPSTREAM FACE AND CREST OF NORTH SECTION OF DAM

PHOTO 4

DOWNSTREAM FACE OF DAM

LAKE WATERLOO DAM
1 MAY 1979

PHOTO 5

UPSTREAM FACE AND CREST OF SOUTH SECTION OF DAM

PHOTO 6

REPAIRED BREACH - SOUTH SECTION OF DAM

LAKE WATERLOO DAM
1 MAY 1979

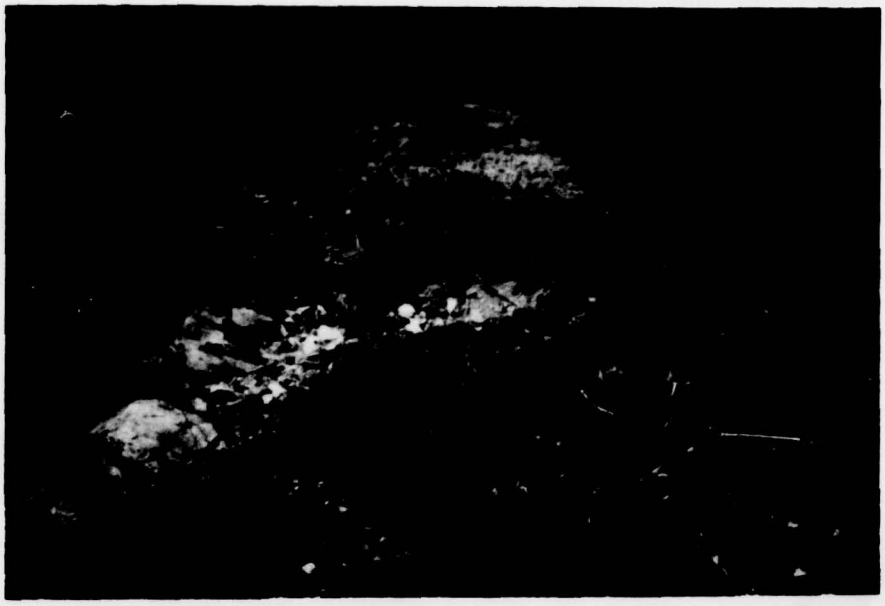


PHOTO 7

ERODED AREA ON DOWNSTREAM FACE OF NORTH SECTION OF DAM

PHOTO 8

OUTLET WORKS

LAKE WATERLOO DAM
1 MAY 1979

PHOTO 9

OUTLET WORKS DISCHARGE CHANNEL

PHOTO 10

DOWNSTREAM CHANNEL

LAKE WATERLOO DAM
1 MAY 1979

APPENDIX 3

Engineering Data

CHECK LIST

HYDROLOGIC AND HYDRAULIC DATA

ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: Wooded & developed with two large lakes

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 648.7 (68 acre-feet)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): N.A.

ELEVATION MAXIMUM DESIGN POOL: 650.7

ELEVATION TOP DAM: 649.8

SPILLWAY CREST: Concrete Weir

a. Elevation 648.0
b. Type Straight weir - inclined upstream face
c. Width 15 feet
d. Length 76 feet
e. Location Spillover Downstream side of dam
f. Number and Type of Gates None

OUTLET WORKS: Open concrete chamber with gates in three sides

a. Type Stoplogs
b. Location Across raceway at north end of dam
c. Entrance inverts 643.2
d. Exit inverts 642.7
e. Emergency draindown facilities: Pull stoplogs

HYDROMETEOROLOGICAL GAGES: None

a. Type N.A.
b. Location N.A.
c. Records N.A.

MAXIMUM NON-DAMAGING DISCHARGE:

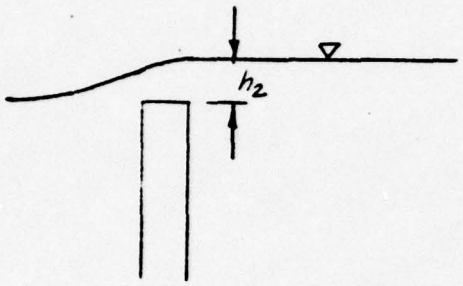
(Lake stage equal to top of dam) 589 c.f.s.

APPENDIX 4

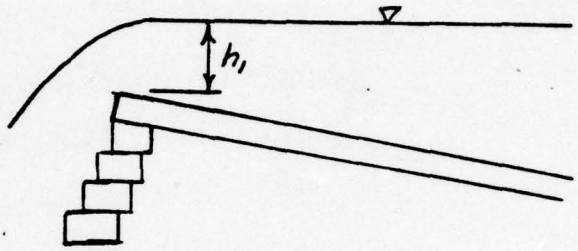
Hydrologic Computations

Spillway Discharge

Discharge from Lake Waterloo occurrs at two locations: spillway and outlet works.



Outlet Works



Spillway

SECTIONS

Discharge coefficients are taken from King, Handbook of Hydraulics. The spillway is assumed to be a weir with inclined upstream face. The average discharge coefficient, C_1, is 2.93. The outlet works is assumed to be a sharp crested weir with average discharge coefficient, C_2, of 3.2.

Since both weirs are low, tailwater will be significant. However, because of the relatively large hydraulic capacity of the downstream channel, it is assumed that the spillway will not become submerged until lake stage rises to approx. 4 ft above the spillway crest. Therefore, discharge coefficients will not be adjusted for submerged conditions.

Discharge, Q, will be calculated using the following formula:

$$Q = c L h^{3/2}$$

where L_1 = 76 ft. for the spillway and L_2 = 8.7 ft. for the outlet works.

Discharge Tabulation

Water Elev.	h_1 (ft.)	Q_1 (cfs)	h_2 (ft.)	Q_2 (cfs)	ΣQ (cfs)	
648.0	0	0	0	0	0	
648.3	0.3	37	0	0	37	
648.5	0.5	79	0.2	3	82	
649.0	1.0	223	0.7	16	239	
649.5	1.5	409	1.2	37	446	
649.8	1.8	538	1.5	51	589	Crest of Dam
650.0	2.0	630	1.7	62	692	
650.5	2.5	880	2.2	91	971	
651.0	3.0	1157	2.7	124	1281	
651.5	3.5	1458	3.2	159	1617	
652.0	4.0	1781	3.7	198	1979	

STORCH ENGINEERS

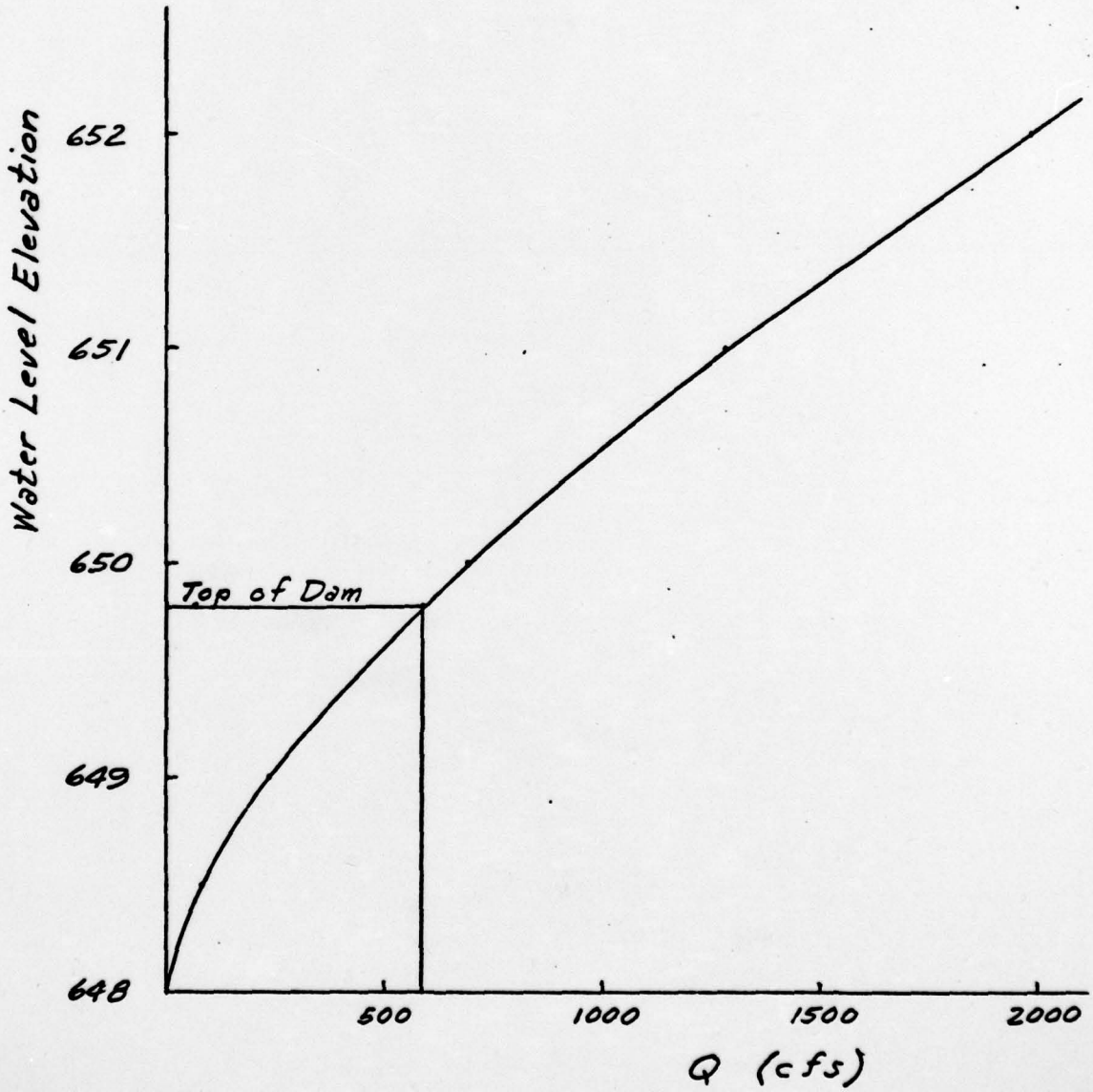
Sheet 4 of 8

Project 1132-B Lake Waterloo Dam

Made By JG Date 7-9-79

Chkd By RL Date 7-17-79

Spillway
Stage Discharge Curve



Hydrology

Drainage area, A, is 62.4 sq. mi.

The 100-year peak flow, Q_{100}, will be determined by adjusting the value for Q_{100} for the Musconetcong River at Hackettstown previously determined by others.

Musconetcong River at Hackettstown:

Q_{100} = 2360 c.f.s.
A = 70 sq. mi.

Using the relationship $\frac{Q_1}{Q_2} = \left(\frac{A_1}{A_2}\right)^{0.75}$, Q_{100} at the dam site is computed as follows:

$$Q_{100} = \left(\frac{62.4}{70}\right)^{.75}(2360)$$

$$= 2165 \text{ c.f.s.}$$

Since this value is greater than the maximum spillway capacity, a routing is necessary.

Inflow Hydrograph

The 100-year hydrograph, determined by adjusting the PMF hydrograph supplied by the U.S. Army Corps of Engineers, is as follows:

Day	Hr.	Q (cfs)	Day	Hr.	Q (cfs)
	6	7		6	81
	12	8		12	73
	18	16		18	66
1	0	59	7	0	61
	6	81		6	57
	12	78		12	52
	18	462		18	48
2	0	1766	8	0	44
	6	2165		6	40
	12	1695		12	38
	18	1336		18	36
3	0	1040	9	0	34
	6	804		6	33
	12	624		12	32
	18	494		18	30
4	0	422	10	0	29
	6	320		6	28
	12	253		12	27
	18	207		18	26
5	0	173			
	6	137			
	12	116			
	18	101			
6	0	90			

Lake Storage Volume

Information from USGS quadrangle and aerial photo

Elev.	Surface Area (acres)
643	0
648.7	36.0
653	73.5
673	340

HEC-1-DB program will develop storage capacity from surface area and elev.

Capacity of Outlet Works

With stoplogs removed from east and south sides of outlet works chamber, assume broad crested weir with length equal to 8.7'.

For normal lake level, $h = 5.5'$

$$Q = cLh^{3/2}$$

$$= (2.6)(8.7)(5.5)^{3/2}$$

$$= 292 \text{ cfs.}$$

For average discharge, $h = 2.75'$ and $Q = 103$ cfs.

Mean inflow (dry season) = 70 cfs.

∴ Net discharge = 103 - 70 = 33 c.f.s.

Time to Lower Lake 5.5'

$$\text{Time} = \frac{\text{Volume}}{\text{Net Discharge}} = \frac{46 \times 43560}{33}$$

$$= 60720 \text{ sec}$$

$$= 17 \text{ hrs.}$$

(Use 1 day.)

HEC-1-DB COMPUTATIONS

```
A1                    NATIONAL DAM SAFETY PROGRAM
A2                  LAKE WATERLOO DAM, NEW JERSEY.
A3                      100 YEAR STORM ROUTING.
B      80       2       0                                0       0       3
B1      3
K       0    LAKE                        0       0       1       0
K1           INFLOW TO LAKE WATERLOO
Y      -1
N       7       7       8       8      11      14      16      30      45      59
N      66      73      81     121     147     200     287     374     462     900
N    1338    1906    2036    2165    2008    1851    1595    1575    1455    1336
N    1237    1139    1040     961     882     804     744     684     624     581
N     537     494     470     446     422     388     354     320     298     275
N     253     238     222     207     196     184     173     161     149     137
N     130     123     116     111     106     101      97      94      90      87
N      84      81      78      76      73      71      68      66      64      63
K       1    DAM                         0       0       1
K1           ROUTE DISCHARGE THRJ DAM
Y                                1       1
Y1      1                                        -648      -1
Y4    648   648.5     649   649.5     650   650.5     651   651.5     652
Y5      0      82     239     446     692     971    1281    1617    1979
$A      0      36    73.5     340
$E    643   648.7     653     673
$$    648
$D  649.8    2.63     1.5     420
K      99
A
A
A
A
A
```

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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********

RUN  DATE= 79/07/13.
     TIME= 09.22.56.
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NATIONAL DAM SAFETY PROGRAM
LAKE WATERLOO DAM, NEW JERSEY.
100 YEAR STORM ROUTING.

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
80	2	0	0	0	0	0	0	3	0

JOPER	NWT	LROPT	TRACE
3	0	0	0

****

SUB-AREA RUNOFF COMPUTATION

INFLOW TO LAKE WATERLOO

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
LAKE	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
-1	0	0.00	0.00	0.00	0.00	0.000	0	0	0

INPUT HYDROGRAPH

7.	7.	8.	8.	11.	14.	16.	30.	45.	59.
66.	75.	81.	121.	147.	200.	287.	374.	462.	900.
1338.	1906.	2035.	2165.	2008.	1851.	1699.	1575.	1455.	1336.
1237.	1139.	1040.	961.	882.	804.	744.	684.	624.	581.
537.	494.	470.	446.	420.	388.	354.	320.	298.	275.
253.	238.	222.	207.	196.	184.	173.	161.	149.	137.
130.	123.	115.	111.	106.	101.	97.	94.	90.	87.
84.	81.	78.	76.	73.	71.	68.	66.	64.	63.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	2165.	2053.	1635.	904.	36045.
CMS	61.	58.	46.	26.	1038.
INCHES		.00	.00	.00	.00
MM		.00	.00	.00	.00
AC-FT		1019.	3243.	5382.	6057.
THOUS CU M		1256.	4000.	6638.	7471.

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTE DISCHARGE THRU DAM

ISTAG	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
DAM	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	2	0	0.000	0.000	0.000	-648.	-1

STAGE	648.00	648.50	649.00	649.50	650.00	650.50	651.00	651.50	652.00
FLOW	0.00	82.00	239.00	446.00	692.00	971.00	1281.00	1617.00	1979.00
SURFACE AREA=	0.	36.	74.	340.					
CAPACITY=	0.	69.	299.	4110.					
ELEVATION=	643.	649.	653.	673.					

CREL	SPWID	COOW	EXPW	ELEVL	COOL	CAREA	EXPL
648.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COOD	EXPD	DAMWID
649.8	2.6	1.5	420.

END-OF-PERIOD HYDROGRAPH ORDINATES

MO.	DA	HR. MN	PERIOD	HOURS	INFLOW	OUTFLOW	STORAGE	STAGE
1	01	2.00	1	2.00	7.	4.	47.	648.0
1	01	4.00	2	4.00	7.	6.	47.	648.0
1	01	6.00	3	6.00	8.	7.	47.	648.0
1	01	8.00	4	8.00	8.	8.	47.	648.0
1	01	10.00	5	10.00	11.	9.	48.	648.1
1	01	12.00	6	12.00	14.	11.	48.	648.1
1	01	14.00	7	14.00	15.	13.	48.	648.1
1	01	16.00	8	16.00	30.	20.	50.	648.1
1	01	18.00	9	18.00	45.	31.	52.	648.2
1	01	20.00	10	20.00	59.	44.	54.	648.3
1	01	22.00	11	22.00	66.	56.	56.	648.3
1	02	0.00	12	24.00	73.	64.	58.	648.4
1	02	2.00	13	26.00	81.	72.	59.	648.4
1	02	4.00	14	28.00	121.	92.	63.	648.5
1	02	6.00	15	30.00	147.	120.	68.	648.6
1	02	8.00	16	32.00	200.	166.	71.	648.8
1	02	10.00	17	34.00	297.	230.	78.	649.0
1	02	12.00	18	36.00	374.	323.	87.	649.2
1	02	14.00	19	38.00	412.	410.	96.	649.4
1	02	16.00	20	40.00	900.	691.	118.	649.9
1	02	18.00	21	42.00	1338.	1308.	137.	650.3
1	02	20.00	22	44.00	1506.	1736.	150.	650.6
1	02	22.00	23	46.00	2039.	2073.	157.	650.7
1	03	0.00	24	48.00	2165.	2115.	155.	650.7
1	03	2.00	25	50.00	2028.	2072.	157.	650.7
1	03	4.00	26	52.00	1851.	1851.	151.	650.6
1	03	6.00	27	54.00	1695.	1730.	146.	650.6
1	03	8.00	28	56.00	1575.	1584.	145.	650.5
1	03	10.00	29	58.00	1455.	1479.	142.	650.4
1	03	12.00	30	60.00	1336.	1358.	139.	650.4
1	03	14.00	31	62.00	1237.	1253.	136.	650.3
1	03	16.00	32	64.00	1139.	1155.	133.	650.2
1	03	18.00	33	66.00	1040.	1058.	130.	650.2
1	03	20.00	34	68.00	961.	974.	128.	650.1
1	03	22.00	35	70.00	882.	899.	125.	650.1
1	04	0.00	36	72.00	804.	820.	123.	650.0
1	04	2.00	37	74.00	744.	756.	120.	650.0
1	04	4.00	38	76.00	684.	699.	118.	649.9
1	04	6.00	39	78.00	624.	641.	115.	649.9
1	04	8.00	40	80.00	581.	596.	113.	649.8
1	04	10.00	41	82.00	537.	550.	110.	649.7
1	04	12.00	42	84.00	494.	517.	106.	649.6
1	04	14.00	43	86.00	470.	483.	103.	649.6
1	04	16.00	44	88.00	446.	459.	101.	649.5
1	04	18.00	45	90.00	422.	435.	98.	649.5
1	04	20.00	46	92.00	388.	408.	96.	649.4
1	04	22.00	47	94.00	354.	374.	92.	649.3
1	05	0.00	48	96.00	320.	340.	89.	649.2
1	05	2.00	49	98.00	298.	311.	86.	649.2
1	05	4.00	50	100.00	275.	288.	84.	649.1
1	05	6.00	51	102.00	253.	266.	82.	649.1
1	05	8.00	52	104.00	238.	247.	80.	649.0
1	05	10.00	53	106.00	222.	232.	79.	649.0
1	05	12.00	54	108.00	207.	218.	77.	648.9
1	05	14.00	55	110.00	195.	204.	75.	648.9
1	05	16.00	56	112.00	184.	193.	74.	648.9
1	05	18.00	57	114.00	173.	181.	73.	648.8
1	05	20.00	58	116.00	161.	169.	71.	648.8
1	05	22.00	59	118.00	149.	157.	70.	648.7
1	06	0.00	60	120.00	137.	145.	68.	648.7
1	06	2.00	61	122.00	130.	136.	67.	648.7
1	06	4.00	62	124.00	123.	128.	67.	648.6
1	06	6.00	63	126.00	116.	121.	66.	648.6
1	06	8.00	64	128.00	111.	115.	65.	648.6
1	06	10.00	65	130.00	106.	110.	64.	648.6
1	06	12.00	66	132.00	101.	104.	64.	648.6
1	06	14.00	67	134.00	97.	100.	63.	648.6
1	06	16.00	68	136.00	94.	96.	63.	648.5
1	06	18.00	69	138.00	90.	93.	63.	648.5
1	06	20.00	70	140.00	87.	89.	62.	648.5
1	06	22.00	71	142.00	84.	86.	62.	648.5
1	07	0.00	72	144.00	81.	83.	62.	648.5
1	07	2.00	73	146.00	78.	81.	61.	648.5
1	07	4.00	74	148.00	76.	79.	61.	648.5
1	07	6.00	75	150.00	73.	77.	60.	648.5
1	07	8.00	76	152.00	71.	74.	60.	648.5
1	07	10.00	77	154.00	68.	72.	59.	648.4
1	07	12.00	78	156.00	66.	69.	59.	648.4
1	07	14.00	79	158.00	64.	67.	58.	648.4
1	07	16.00	80	160.00	63.	65.	58.	648.4

SUMMARY OF DAM SAFETY ANALYSIS

.....		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	648.00	648.00	649.80
	STORAGE	46.	46.	113.
	OUTFLOW	0.	0.	594.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.00	650.73	.93	158.	2115.	42.00	48.00	0.00

APPENDIX 5

Bibliography

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